660L

PUBLIC LIBRARY OF THE CITY OF DETROIT

BULLETIN

OF THE

Geological Society of America

VOLUME 21 NUMBER 1
MARCH, 1910

JOSEPH STANLEY-BROWN, EDITOR

NEW YORK
PUBLISHED BY THE SOCIETY
MARCH, JUNE, SEPTEMBER, AND DECEMBER

CONTENTS

	Pages
Proceedings of the Twenty-second Annual Meeting. By Edmund Otis Hovey, Secretary	1–41
Constitution and By-Laws	42–48
Publication Rules	49–52
Officers, Correspondents, and Fellows	53–68
Paleontological Society: Meetings, Constitution and By-Laws, and Officers and Members. By Herdman F. Cleland, Secretary	69–86
Origin of the Alkaline Rocks. By Reginald A. Daly	87–118
Evidence that the Fossiliferous Gravel and Sand Beds of Iowa and Nebraska are Aftonian. By B. Shimek	119–140

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA

Subscription, $10 per year to individuals residing in North America; $7.50 to institutions and libraries and to individuals residing elsewhere than in North America.

Communications should be addressed to The Geological Society of America, care of 420 11th Street N. W., Washington, D. C., or 77th Street and Central Park, West, New York City.

Entered as second-class matter in the Post-Office at Washington, D. C., under the Act of Congress of July 16, 1894

PRESS OF JUDD & DETWEILER, INC., WASHINGTON, D. C.

1337

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
VOL. 21, PP. 1-68, PL. 1 MARCH 31, 1910

PROCEEDINGS OF THE TWENTY-SECOND ANNUAL MEETING OF THE GEOLOGICAL SOCIETY OF AMERICA, HELD AT BOSTON AND CAMBRIDGE, MASSACHUSETTS, DECEMBER 28, 29 30, AND 31, 1909[1]

EDMUND OTIS HOVEY, *Secretary*

CONTENTS

	Page
Session of Tuesday, December 28	2
Election of Auditing Committee	2
Election of Officers, Fellows, and Correspondents	2
Memoir of Persifor Frazer (with bibliography); by R. A. F. Penrose, Jr.	5
Memoir of Daniel W. Langton, Jr. (with bibliography); by E. A. Smith	12
Report of the Committee on the Formation of the Paleontological Society	16
Report of the Publication Committee	17
Amendments to the Constitution and By-Laws	19
Report of the Photograph Committee	19
Titles of papers and names of disputants	20
Session of Wednesday, December 29	23
Report of the Auditing Committee	23
Titles of papers and names of disputants	23
Session of Thursday, December 30	28
Resolution concerning Antarctic research	28
Report of the Committee on Geologic Nomenclature	29
Report of the Committee on the Nomenclature of Faults	29
Titles of papers and names of disputants	29
Sessions of the Paleontological Section, December 29, 30, and 31	34
Cordilleran Section	34
Report of the Council	35
Secretary's report	35
Treasurer's report	37
Editor's report	39

[1] The business sessions of the twenty-second annual meeting of the Society were held in the rooms of the departments of Geology, Mineralogy, and Botany of the University Museum, Harvard University. The meetings in general were presided over by First Vice-President F. D. Adams in the absence of President G. K. Gilbert, who was detained by ill health in Washington, D. C.

QE1

Page
Register of the Boston-Cambridge Meeting, 1909..... 40
Constitution and By-Laws..... 42
Publication rules of the Geological Society of America..... 49
Officers, Correspondents, and Fellows of the Geological Society of America. 53

Session of Tuesday, December 28

The first session of the Society was called to order at 10 o'clock a. m., Tuesday, December 28, in the lecture hall of the Department of Geology, University Museum, Cambridge, Mass., by Vice-President Adams, who, after a few fitting words with reference to the absent President, announced that the submission of the Council Report would necessarily be deferred, since it had not yet been received from the printers.

Election of Auditing Committee

Nominations for the Auditing Committee to examine and report upon the Treasurer's books and vouchers and the securities in his custody were then called for. F. L. Ransome, H. Ries, and S. F. Emmons were nominated and duly elected as this committee.

Election of Officers, Fellows, and Correspondents

The declaration of the votes for officers for 1910, for Fellows, and for Correspondents being next in order, the Secretary announced the election in due form of the regular tickets, as follows:

Officers for 1910

President:

Arnold Hague, Washington, D. C.

First Vice-President:

Charles Schuchert, New Haven, Conn.

Second Vice-President:

A. P. Low, Ottawa, Ont.

Secretary:

Edmund Otis Hovey, New York City.

Treasurer:

WILLIAM BULLOCK CLARK, Baltimore, Md.

Editor:

JOSEPH STANLEY-BROWN, Cold Spring Harbor, N. Y.

Librarian:

H. P. CUSHING, Cleveland, Ohio.

Councilors:

J. B. WOODWORTH, Cambridge, Mass.
C. S. PROSSER, Columbus, Ohio.

FELLOWS

WILLIAM CLINTON ALDEN, A. B. (Cornell College); A. M., Ph. D. (Chicago), Washington, D. C. Assistant Geologist, U. S. Geological Survey.

WALLACE WALTER ATWOOD, B. S., Ph. D. (Chicago, '97, '03), Chicago, Illinois.

EDSON SUNDERLAND BASTIN, A. B. (Michigan, '02); A. M. (Chicago, '03), Washington, D. C. Assistant Geologist, U. S. Geological Survey.

EDWARD WILBER BERRY, Baltimore, Md. Instructor in Johns Hopkins University.

WILLIS STANLEY BLATCHLEY, A. B., A. M. (Indiana, '87, '91), State House, Indianapolis, Indiana. State Geologist of Indiana.

HENRY ANDREW BUEHLER, B. S. (Wisconsin, '01), Rolla, Missouri. State Geologist of Missouri.

FRED HARVEY HALL CALHOUN, B. S., Ph. D. (Chicago, '93, '02), Clemson College, South Carolina. Professor of Geology and Mineralogy, Clemson College, and Assistant Geologist, U. S. Geological Survey.

ARTHUR LOUIS DAY, B. A., Ph. D. (Yale, '92, '94), Washington, D. C. Director, Geophysical Laboratory, Carnegie Institution of Washington.

FRANK WALBRIDGE DE WOLF, S. B. (Chicago, '03), Urbana, Illinois. Assistant State Geologist of Illinois and Assistant Geologist, U. S. Geological Survey.

JAMES WALTER GOLDTHWAIT, A. B., A. M., Ph. D. (Harvard, '02, '03, '06), Hanover, New Hampshire. Assistant Professor of Geology in Dartmouth College and head of department.

BAIRD HALBERSTADT, Pottsville, Pennsylvania. Engineer and Geologist.

OSCAR H. HERSHEY, Kellogg, Idaho. Engaged in private practice.

FREDERICK BREWSTER LOOMIS, B. A. (Amherst); Ph. D. (Munich), Amherst, Massachusetts. Professor of Comparative Anatomy in Amherst College.

RICHARD SWANN LULL, B. S., M. S. (Rutgers, '93, '96); Ph. D. (Columbia, '03), New Haven, Connecticut. Assistant Professor of and Associate Curator in Vertebrate Paleontology, Yale University.

GEORGE ROGERS MANSFIELD, B. S., A. M. (Amherst, '97, '01); A. M., Ph. D. (Harvard, '04, '06), Evanston, Illinois. Assistant Professor of Geology, Northwestern University.

LAWRENCE MARTIN, A. B. (Cornell, '04); A. M. (Harvard, '06), Madison, Wisconsin. Instructor in Geology, University of Wisconsin, and Geologic Aid, U. S. Geological Survey.

SAMUEL WASHINGTON MCCALLIE, Ph. B. (Tennessee Wesleyan), Atlanta, Georgia. State Geologist of Georgia.

WILLIAM JOHN MILLER, S. B. (Pacific, '00); Ph. D. (Johns Hopkins, '05), Clinton, New York. Professor of Geology and Mineralogy in Hamilton College.

MALCOLM JOHN MUNN, Washington, D. C. Assistant Geologist, U. S. Geological Survey.

EDWARD ORTON, JR., E. M. (Ohio State University, '84), Columbus, Ohio. Director, Department of Ceramic Engineering, Ohio State University, and Assistant Geologist, Geological Survey of Ohio.

PHILIP S. SMITH, A. B., A. M., Ph. D. (Harvard, '99, '00, '04), Washington, D. C. Assistant Geologist, U. S. Geological Survey.

WARREN DU PRÉ SMITH, B. S. (Wisconsin, '02); A. M. (Leland Stanford, Jr., '04); Ph. D. (Wisconsin, '08), Manila, Philippine Islands. Chief of the Mining Bureau.

CYRUS FISHER TOLMAN, JR., B. S. (Chicago, '96), Tucson, Arizona. Professor of Geology and Mining in the University of Arizona.

CHARLES WILL WRIGHT, B. S. and M. E. (Michigan College of Mines, '03), Washington, D. C. Assistant Geologist, U. S. Geological Survey.

CORRESPONDENTS

CHARLES BARROIS, Professor of Geology at the University, Lille, France.

W. C. BRÖGGER, Professor of Geology and Mineralogy at the Royal University, Christiania, Norway.

SIR ARCHIBALD GEIKIE, President of the Royal Society, late Director General of the Geological Survey of the United Kingdom, Hasslemere, England.

ALBRECHT HEIM, President of the Swiss Geological Commission, Professor of Geology at the University, Zürich, Switzerland.

EMANUEL KAYSER, Professor of Geology at the University, Marburg, Germany.

EDUARD SUESS, Professor (retired) of Geology at the Imperial-Royal University, President of the Academy of Sciences, Vienna, Austria.

FERDINAND ZIRKEL, Professor (retired) of Mineralogy and Geology at the University of Leipzic, Bonn, Germany.

The Secretary announced the death during the past year of Persifor Frazer and Daniel W. Langton. The memorials of these members, read by title, were as follows:

PERSIFOR FRAZER

MEMOIR OF PERSIFOR FRAZER

BY R. A. F. PENROSE, JR.

Dr. Persifor Frazer was born in Philadelphia, July 24, 1844, and died in the same city April 7, 1909. He was the son of John Fries Frazer and Charlotte Cave Frazer. His family were among the early settlers of Pennsylvania in the colonial days, having come originally from Scotland, and the town of Frazer, in eastern Pennsylvania, was named for the Frazer family in America. The Frazers have always been prominent in the affairs of the State and nation. Gen. Persifor Frazer, the son of the first of the family in America, was the great-grandfather of Dr. Persifor Frazer, and commanded with distinction in the Revolutionary War. Robert Frazer, the grandfather of Dr. Persifor Frazer, was an eminent lawyer in Philadelphia and a member of the Pennsylvania legislature.

John F. Frazer, LL. D., the father of Persifor Frazer, was professor of chemistry for many years at the University of Pennsylvania, and also vice-provost of the same institution. He was one of the most eminent scientific men of his time in America, and there still live men who can recall with pleasing remembrance the informal Sunday evening gatherings at Professor Frazer's house in Philadelphia, where the scientific questions of the day were discussed. In these weekly assemblages were to be found such men as Dr. John L. Le Conte, Professors Genth and Lesley, and other local scientists, as well as scientists from elsewhere, who happened by chance to be in Philadelphia. His hospitality to his fellow-workers became known far beyond the limits of the city, and many a man of science found a congenial haven at his house.

Persifor Frazer was brought up among these surroundings, and his natural inclination for science had every opportunity to develop in such an atmosphere. One of the earliest traits that manifested itself in him was his remarkable versatility, and nothing in any branch of science or human affairs failed to interest him. This trait was rapidly developed in his youth by intercourse with the masters of various branches of science who assembled at his father's house; and no better evidence of his versatility is shown than the fact that in later life he acquired eminence in three distinct branches of learning—chemistry, geology, and the study of handwriting. He was also an accomplished linguist, speaking French and German as he would English, and with this he combined remarkable powers as a conversationalist and speaker. As a public lecturer he always commanded the respect and attention of his audience by his eloquent and lucid address. In another direction his versatility was shown when he served with marked credit and distinction in both the Army and

the Navy during the Civil War. He was also devoted to athletics and was noted for his prowess in fencing and sparring.

Persifor Frazer's early training was in Saint Lukes Parish School, and later in the schools of Samuel Arthur and of Rev. John W. Faires, all in Philadelphia. In 1858 he entered the University of Pennsylvania, from which he graduated with the degree of A. B. in 1862. He received the degree of A. M. from the same institution in 1865. Immediately after leaving college in 1862 he joined the United States Coast Survey, and was connected with the South Atlantic squadron in 1862 to 1863. The Civil War was then at its height, and Frazer returned North, enlisted with the First Troop, Philadelphia City Cavalry, and fought through the Gettysburg campaign in 1863. Later he joined the United States Navy as acting ensign, and served in the Mississippi squadron until the end of the war, when he received an honorable discharge and an expression from the Navy Department of its high appreciation of his services.

After the close of the war, Frazer studied chemistry for a few months with the firm of Messrs. Booth and Garrett, in Philadelphia. In 1866 he went to Germany to continue his scientific studies, and attended the Royal Saxon School of Mines at Freiberg from 1866 to 1869. On his return to America in the latter year he became mineralogist and metallurgist to the United States Geological Survey under Hayden, in which position he carried on explorations in Colorado and New Mexico and wrote reports on the results of his work. He remained on the U. S. Geological Survey until 1870, when he was appointed instructor in "natural philosophy and chemistry" at the University of Pennsylvania, a department in which his father was then head professor. In 1871 he was elected assistant professor in the same department, and on the death of his father, in 1872, he succeeded him as head of the department. In 1873 the chair of natural philosophy and chemistry was divided into two professorships, one of chemistry and one of physics, and Frazer was appointed professor of chemistry.

Though a most efficient and able chemist, Frazer's inclinations seem to have been more strongly in the direction of geology. His education in this subject at Freiberg and on the U. S. Geological Survey under Hayden led him to seek for the reëstablishment of a geological survey in Pennsylvania. The previous geological survey of Pennsylvania had long since been discontinued for lack of an appropriation from the legislature, but as the result of the persistent efforts of a number of scientific men in Pennsylvania, among whom was Frazer, the legislature, in 1874, made an appropriation for a new geological survey of the State. Prof. J. P. Lesley was appointed head of the survey, and Frazer resigned

his professorship of chemistry to take charge of the geological work in some of the counties in the southeastern part of the State. The geology in this region is in many cases very complicated, and the highest scientific ability was required in solving the many problems involved. Frazer, however, showed himself thoroughly capable of handling the task, and in a masterly way he worked out the structure and other intricate geological problems of the region in great detail. This work brought him more into the public eye and gave him more prominence than anything he had previously done. Four volumes of the publications of the Second Geological Survey of Pennsylvania and a monograph in another volume attest to the energy with which he pursued his geological researches during the eight years in which he was connected with that organization.

In 1881 Frazer was general manager of the Central Virginia Iron Company. Somewhat later he took up the practice of his profession as consulting and reporting geologist, chemist, metallurgist, and mining engineer, and continued in it for many years. This led him to many different parts of the United States and foreign countries, and his numerous papers published during this period prove his activity in his investigations, and also show that, though engaged on the commercial side of his profession, he never lost his interest in the purely scientific side.

While in France in 1881-1882 Frazer received the degree of Docteur ès-Sciences Naturelles from the Université de France, being the first foreigner to whom this degree had ever been given. It was conferred upon him after a rigid examination and on the presentation of a thesis entitled "Mémoire sur la géologie de la partie sud-est de la Pennsylvanie." In 1890 again the French Government honored him with the title of Officier de l'Instruction Publique.

In 1880-1881 Doctor Frazer was vice-president of the American Institute of Mining Engineers, and in 1907 he was vice-president of the council of the same society. In 1885 he represented the American Association for the Advancement of Science before the Royal Society of Canada, and in the same year he was chosen secretary of the American Committee of the International Geological Congress. In 1888 he was appointed vice-president of the same committee at the meeting of the International Geological Congress held in London that year, and in 1897 he was again chosen vice-president of this committee at the meeting of the International Geological Congress held in Saint Petersburg.

Doctor Frazer was one of the founders of the "American Geologist" and was one of its editors from 1888-1905. In 1889 he was chosen professor of horticultural chemistry by the Horticultural Society of Penn-

sylvania, another evidence of his diversified talents and interests. In 1896-1898 he was secretary of the American Philosophical Society.

Some of the most active and efficient work of Doctor Frazer's life was done in connection with the Franklin Institute of Philadelphia. In 1882 he was appointed professor of chemistry there, a position that had been held by his father before him. For many years he was one of the editors of the Journal of the Franklin Institute, and was a prolific writer for it on many subjects. He was also one of the board of managers of the institute, and did much to add to its welfare, as well as to the general regard and respect in which it was held by the community. Probably in none of the many fields of his activities did Doctor Frazer do more good than in the Franklin Institute, and his labors in its behalf continued almost up to the day of his death.

Frazer's remarkable facility for letter writing in his own and other languages, and the ease and grace with which he could express himself, made him valuable as a corresponding member of many scientific societies, both in his own country and abroad. He was elected corresponding member of the New York Academy of Sciences in 1885, of the k. k. Geologische Reichanstalt in 1886, of the Sociedad Cientifica "Antonio Alzate" of Mexico in 1891, and honorary member of the Société Géologique de Belgique in 1897.

Doctor Frazer belonged to many scientific and patriotic societies, the diversity of which show his varied interests. He was a fellow of the Geological Society of America, and of the American Association for the Advancement of Science, a member of the American Philosophical Society, Philadelphia Academy of Natural Sciences, Franklin Institute, Pennsylvania Historical Society, Pennsylvania Horticultural Society, American Institute of Mining Engineers, British Association for the Advancement of Science, Société Géologique du Nord (France), Société Géologique de Belgique (Belgium), k. k. Reichsanstalt (Austria), Sociedad Cientifica "Antonio Alzate" (Mexico), Society of American Authors, Military Order of the Loyal Legion, Society of the Cincinnati, Naval Veteran Association, Society of the War of 1812, Society of Colonial Wars in the Commonwealth of Pennsylvania, Pennsylvania Society, Sons of the Revolution, etcetera.

Though geology and chemistry were the branches of science to which Doctor Frazer devoted most of his time, yet in the later years of his life he became noted in his researches in the characteristics of handwriting and the study of manuscript documents, and some of the discoveries he made were original and unique. In 1894 he published a book on "Bibliotics; or, the study of documents," which excited much favorable com-

ment both in this country and abroad. In 1906, in connection with these researches, he was awarded the John Scott medal by the city of Philadelphia for his invention of a colorimeter, or an instrument by which, with the help of certain prisms, he could determine the relative intensity and color value of ink marks in handwriting. Later on he took up the study of the Bertillon system of identification, and visited Bertillon in Europe to discuss his methods with him. He was actively engaged in this work at the time of his death, and in fact his last public address was on this subject in the winter of 1909. His friends noticed at that time that he did not seem well, but he was not considered seriously ill until within a few days of the fatal attack of heart trouble that carried him away.

In 1871 Doctor Frazer married Miss Isabella Nevins Whelen. They had four children—three sons, Persifor, Lawrence, and John, and a daughter, Charlotte. Mrs. Frazer and all the children except Lawrence, who died in childhood, survive him. During the whole of Doctor Frazer's lifetime, after the death of his father, he kept up the Sunday evening gatherings in which the latter had taken so much pleasure, and they were attended both by his father's and his own friends. His intimate friends were not numerous, for he did not court popularity. He was self-reliant and a hard worker, as is shown by his many publications and accomplishments, and most of his time was spent either in the field or in his study.

Dr. John L. Le Conte,[2] in writing in 1873 about the father of Doctor Frazer, described him in the following words, which are also singularly applicable to the son:

> "A man of eminent scientific and general culture; of singular truthfulness of speech, and integrity of conduct; a devoted lover of consistency in action, and strict performance of duty, virtues which he exemplified in himself and sought for in others."

One of Doctor Frazer's most marked traits was his respect for the truth, and when once convinced that his opinion was right, he would brook no opposition, and often caused offense to others by the vigor with which he defended his opinions. But there was no malice in his methods of controversy; he always fought in the open, and the more bitter the argument in which he was involved, the more his opponents realized that they were contending with a strong man, strong in his intellectuality, strong in his convictions, strong in his capacity to fight, seeking for truth as he saw it. Hence, no matter how much they may have differed from him in opinion, they respected his virility and sincerity.

[2] Proceedings of the American Philosophical Society, vol. 13, 1873, pp. 183-190.

BIBLIOGRAPHY[3]

Mines and minerals of Colorado. Report of U. S. Geological Survey of Colorado and New Mexico under F. V. Hayden. Third Annual Report, pp. 201-228. Washington, 1873.

On the geology of certain lands in Ritchie and Tyler counties, West Virginia. Proceedings of the Philadelphia Academy of Sciences, vol. 26, 1874, pp. 168-172.

Hydro-Geology. Transactions of the American Institute of Mining Engineers, vol. 3, 1875, pp. 108-115.

Report of progress in the district of York and Adams counties. Second Geological Survey of Pennsylvania, 1874, Report C, VIII, 198 pages, 8 plates, 2 maps. Harrisburg, 1876.

Origin of the Lower Silurian limonites of York and Adams counties. Proceedings of the American Philosophical Society, vol. 14, 1876, pp. 364-370.

On the traps of the Mesozoic sandstones in York and Adams counties, Pennsylvania. Proceedings of the American Philosophical Society, vol. 14, 1876, pp. 402-414, plate.

Report of progress in the counties of York, Adams, Cumberland, and Franklin. Second Geological Survey of Pennsylvania, 1875, Report CC, pp. 198-400, plates, maps. Harrisburg, 1877.

Regarding some Mesozoic ores. Proceedings of the American Philosophical Society, vol. 16, 1877, pp. 651-655, 664-665.

The position of the American new red sandstone. Transactions of the American Institute of Mining Engineers, vol. 5, 1877, pp. 494-501.

A study of the specular and magnetic iron ores of the new red sandstone in York County, Pennsylvania. Transactions of the American Institute of Mining Engineers, vol. 5, 1877, pp. 132-143.

The geology of Lancaster County. Second Geological Survey of Pennsylvania, Report CCC, x + 350 pages, with atlas of plates and maps. Harrisburg, 1880. Abstract, American Naturalist, vol. 15, 1881, pp. 161-162.

On the physical and chemical characteristics of a trap at Williamsons Point, Pennsylvania. Proceedings of the American Philosophical Society, vol. 18, 1880, pp. 96-103.

Some copper deposits of Carroll County, Maryland. Transactions of the American Institute of Mining Engineers, vol. 9, 1881, pp. 33-40, map.

The Whopperlode, Gunnison County, Colorado. Transactions of the American Institute of Mining Engineers, vol. 9, 1881, pp. 249-258.

Review of Report C^3, Second Geological Survey of Pennsylvania. American Naturalist, vol. 17, 1882, pp. 1020-1027.

The iron ores of the Middle James River. Transactions of the American Institute of Mining Engineers, vol. 11, 1883, pp. 201-216, map.

Rand's criticism of (vol. C^1) geology of Chester County, Pennsylvania. Journal of the Franklin Institute, 3d series, vol. 86, 1883, pp. 274-278.

The horizon of the South Valley Hill rocks in Pennsylvania. Proceedings of the American Philosophical Society, vol. 20, 1883, pp. 510-518.

[3] The titles given are only those of the more important geological and mineralogical publications of Doctor Frazer.

Geological notes in the several townships of Chester County. Edited by J. P. Lesley. Reviewed by P. Frazer, American Naturalist, vol. 17, 1883, pp. 1020-1027.

Notes from the literature on the geology of Egypt and examination of the syenitic granite of the obelisk in New York. Transactions of the American Institute of Mining Engineers, vol. 11, 1883, pp. 353-366, 376-379. Abstract, Science, vol. 2, 1885, p. 111.

Geological and mineral studies in Nuevo Leon and Coahuila. 36 pages, maps. Philadelphia, 1884.

The northern serpentine belt in Chester County, Pennsylvania. Transactions of the American Institute of Mining Engineers, vol. 12, 1884, pp. 349-355.

The Peach Bottom slates of southeastern York and southern Lancaster counties, Pennsylvania. Transactions of the American Institute of Mining Engineers, vol. 12, 1884, pp. 355-359, plates, map.

Certain silver and iron mines in the states of Nuevo Leon and Coahuila, Mexico. Transactions of the American Institute of Mining Engineers, vol. 12, 1884, pp. 537-569, plates.

The Centennial and Lotta gold properties, Coahuila, Mexico. Transactions of the American Institute of Mining Engineers, vol. 14, 1886, pp. 196-205.

Reply to T. D. Rand's paper, "Notes on the geology of Chester Valley and vicinity," in Proceedings of the Academy of Natural Sciences, Philadelphia, 1883. Journal of the Franklin Institute, 3d series, vol. 87, 1884, pp. 303-307, 309-310.

Report of the American Committee of Delegates to the Berlin International Geological Congress, held September 28 to October 3, 1885. American Journal of Science, 3d series, vol. 30, 1885, pp. 454-475.

Sketch of the geology of York County, Pennsylvania. Proceedings of the American Philosophical Society, vol. 23, 1886, pp. 391-410, map.

A short history of the origin and acts of the International Congress of Geologists and of the American Committee of Delegates to it. American Geologist, vol. 1, 1888, pp. 3-11, 86-100.

Report of the subcommittee on the Archean. American Committee of the International Congress of Geologists, Reports, 1888, A, p. 74, 1888. American Geologist, vol. 2, 1888, pp. 144-192, without Appendix 3.

An unjust attack. (Reply to articles concerning the American Committee of the International Congress of Geologists, by Prof. J. D. Dana and Maj. J. W. Powell, in the American Journal of Science for December, 1888.) American Geologist, vol. 3, 1889, pp. 65-72.

The session of the International Geological Congress in Philadelphia. American Geologist, vol. 5, 1890, pp. 208-212.

The Warrior coal field of northern Alabama. American Geologist, vol. 7, 1891, pp. 305-320.

The sixth session of the International Congress of Geologists. American Geologist, vol. 14, 1894, pp. 259-271.

Tables for the determination of minerals by physical properties ascertainable with the aid of a few field instruments. J. B. Lippincott & Co., Philadelphia, 4th edition, 1897.

Notes on the northern Black Hills of South Dakota. Transactions of the American Institute of Mining Engineers, vol. 27, 1898, pp. 204-231.

The eighth session of the International Congress of Geologists. American Geologist, vol. 27, 1901, pp. 335-342.

History of the Caribbean islands from a petrographic point of view. (Abstract.) Proceedings of the Philadelphia Academy of Natural Sciences, vol. 55, 1903, pp. 396-400.

Geogenesis and some of its bearings on economic geology. Transactions of the American Institute of Mining Engineers, vol. 35, 1905, pp. 298-308.

The classification of coals. Discussion of paper by M. R. Campbell. Transactions of the American Institute of Mining Engineers, vol. 36, 1906, pp. 825-833 (Bi-Monthly Bulletin, No. 8, March, 1906, pp. 239-246).

MEMOIR OF DANIEL W. LANGTON, JR.

BY EUGENE A. SMITH

The subject of this sketch was born May 5, 1864, in Mobile county, Alabama. His father, Daniel W. Langdon,[4] Sr., for a number of years had charge of a nursery garden belonging to his uncle, Hon. Charles C. Langdon, at Langdon Station, on the Mobile and Ohio Railroad, a few miles north of Mobile, and was also upon the staff of the Mobile Register. The uncle was a prominent man in State politics for many years, was a member of the legislature, trustee of the A. & M. College, etcetera. The Langdons were of New England extraction, but the uncle and nephew spent most of their lives in Alabama.

Young Langton spent his early years at his father's home at Langdon Station under the tutelage of his mother, a woman of exceptionally wide reading and information. In addition to the formal teaching, she kept him supplied with all available periodicals and magazines, thus developing in him an interest in current events and a taste for general reading which he never lost. As a youth he attended a private school in the city of Mobile kept by Prof. Amos Towle, by whom he was prepared for college. While at school in Mobile young Langton was a member of the household of his kinsman, Col. William A. Buck, whose home was in Summerville, a suburb of Mobile. The Buck family is one of the most cultured and prominent of the older families of this section of the State, and with such surroundings the boy had unusual opportunities for mental development.

In the autumn of 1879 he entered the University of Alabama, from which institution he was graduated with the degree of Bachelor of Arts in 1882. From the same institution he received in 1888 the degree of Master of Arts, and in 1892 that of Doctor of Philosophy.

[4] The family in Alabama spelled the name Langdon, but the subject of this sketch, after he established himself in New York, adopted the spelling Langton, since he found that to be the original spelling of the name.

As a student of the university he was always much interested in the natural sciences, due in great part, no doubt, to his early training in the nursery gardens of his father, for even as a child he was familiar with the names and properties of most of the ornamental and useful plants. Immediately after his graduation, in the summer of 1882, he became associated with the present writer in geological work in the coastal plain of Alabama, which association continued until he finally left the university in 1889. At this time we were engaged in the study of the Tertiary and Cretaceous formations of this section, and many months were spent by us together in examining the banks of the Tombigbee and Alabama rivers, our means of transportation being a skiff paddled by ourselves. After we had established the succession of the strata along these rivers, he carried on the work independently between the Alabama and the Chattahoochee rivers, and on this latter river, in November, 1887, he made the capital discovery of the marine Miocene formations exposed in the bluffs from Chattahoochee Landing to Alum Bluff. To these formations he gave the name Chattahoochee, but later students of this section have restricted the name to the lower beds of the series.

During this period, as his whole time was not given to the Geological Survey, he spent some months in Mexico in the interests of a mining company, and also in the Alabama coastal plain collecting for Mr. Aldrich.

At commencement of 1889 he received the appointment of assistant chemist in the university, the present writer being at that time professor of chemistry and geology. Before the opening of the next college year, however, he received and accepted an offer from the Baltimore and Ohio Railroad to be consulting geologist of that road, so that he did not take up his work in the university.

He remained with the Baltimore and Ohio Railroad as their consulting geologist for about two years, examining and reporting on mineral lands, mainly coal and iron, for this company. In the course of these investigations he became interested in some coal lands in West Virginia, with the result later of developing a property known as the Turkey Knob mine. Of this enterprise he became the manager or superintendent. After a somewhat protracted struggle the mine was compelled to shut down because it was impossible to get from the railroad the cars necessary to handle the output. His experiences here fully convinced him of the fact that a small operator could not get a "fair deal" under the then existing conditions of railroad management. It is possible that the same conditions obtain at the present day.

Leaving West Virginia, he went to New York City, where he opened an office as consulting geologist and engineer. While in this business his attention was directed to landscape architecture, and he gradually drifted into this line of work, for which his early experiences in his father's gardens gave him a natural bias, and he soon rose to eminence in his profession. His first work in this new line was in Princeton, New Jersey, but he always kept his office in New York. His landscape plans were carried out for several estates in the counties of Long Island and in New Jersey and Pennsylvania. He designed and executed the great West Side Park in Jersey City, and also the park at Harrison, New Jersey, both being parts of a scheme of parks in Hudson County, New Jersey. He was a charter member of the American Society of Landscape Architects, which was organized about 1898. In 1901 he went abroad to collect photographs for a book on Italian Gardens which he was to prepare for Forbes & Co., publishers, but by reason of some disagreement between himself and the publishers, he withdrew, and his name did not appear in connection with the book.

Naturally gifted with artistic tastes, these were developed in his landscape work, and after his marriage, in August, 1896, to Berenice Francis, herself an artist and pupil of Rodin and St. Gaudens, their home in New York became a meeting place for artists alike of pen and pencil.

Both Langton and his wife were brilliant talkers, and their associates were all of congenial spirits. After changing his residence to Morristown, New Jersey, where he built a home, he still kept open house for his artist friends, and week-end meetings of these were as a matter of course. His offices remained in the city. With these surroundings, however, he never lost his early love for geology, and he was often heard to wish that he could afford to go back to the old delightful occupation.

He was a firm believer in the power for good of college associations, and was very active in organizing at the University of Alabama the Sigma Nu fraternity, of which he was regent from 1885 to 1890. To the end of his life he took great interest in this fraternity, and attended its meetings whenever it was possible. Along with his interest in the fraternities went a larger interest in university men as such, and we find him a member of the University Club in the cities in which he lived for any length of time.

He was fond of argument and could generally find something to say for his side of the question, and it must be confessed that not infrequently his side would be that opposed to the common opinion. This, together with his usually emphatic way of expressing his views, gained for him the reputation of being somewhat eccentric.

He was a man of strong prejudices, which is about the same as saying he loved his friends and hated his enemies; but for many of his dislikes there seemed, to an onlooker, to be no very special reason. Perhaps it was a case of "Doctor Fell." On the other hand, his friends, or those who knew him intimately, were quite as devoted to him as he was to them.

As a companion in field work he was all that could be desired; his enthusiasm in collecting shells and in the observation of geological phenomena knew no bounds, and it was with difficulty that he could be "moved on" from a good collecting ground. In the trips which he took alone he had many mishaps; he had a faculty for taking the wrong road while driving through the country, often bringing up at the most unexpected places. His inveterate habit of whistling, which absorbed much of his attention, was partly to blame for this; but, in addition to that, his sense of direction or locality was not very highly developed.

In his canoe trips down Cobecuh and Pea rivers, with only a negro man for companion, his boat was capsized a number of times, and on one occasion, on Pea River, everything in the boat was lost, including the gun of his negro companion. On the next day we find the following note, December 12, 1888: "Stephen Wolf, my negro, rendered disconsolate by the loss of his gun, deserted me about 5 p. m., and left me to continue my voyage alone. The river is filled with shoals, and at every shoal there is a fish trap (almost a man trap), and today I crossed no less than twenty-six. Twice today I took involuntary baths, but fortunately nothing but my person was damped, not even my geologic ardor." "Advice to any geologist who in future may contemplate this trip: Don't." This is fairly characteristic of the man; though subject to occasional spells of depression, he was for the most part bright and cheerful, and disposed to look upon the bright side of every question.

When we look upon his career, cut short by an untimely death, and consider that he so soon won his way to eminence in his chosen profession, and that without outside aid and solely by his own exertions, we can not withhold our tribute of respect and admiration.

His death occurred at his home, near Morristown, New Jersey, on the 21st of June, 1909.

Bibliography

Observations on the Tertiary of Mississippi and Alabama, with descriptions of new species. American Journal of Science, 3d series, vol. 31, 1886, pp. 202-209.

Some Florida Miocene. American Journal of Science, 3d series, vol. 38, 1889, pp. 322-324.

Geology of Mon Louis Island, Mobile Bay. American Journal of Science, 3d series, vol. 40, 1890, pp. 237-238

Variations in the Cretaceous and Tertiary strata of Alabama. Bulletin of the Geological Society of America, vol. 2, 1891, pp. 587-605, 606, plate 23. Abstract, American Geologist, vol. 8, 1891, p. 260.

Geological section along the Chattahoochee River from Columbus to Alum Bluff. Georgia Geological Survey, 1st Report, 1891, pp. 90-97.

Leaf impressions in the Eocene Tertiary of Alabama. Science, vol. 21, 1893, pp. 94-95 (correspondence).

The Loop Creek, West Virginia, coal fields. Colliery Engineering, vol. 16, 1896, p. 122.

REPORT OF THE COMMITTEE ON THE FORMATION OF THE PALEONTOLOGICAL SOCIETY

The report of the Committee on the Formation of the Paleontological Society was presented through its chairman, W. B. Clark, as follows:

On February 13, 1909, at the American Museum of Natural History, New York City, your committee, composed of W. B. Clark, chairman, and Messrs. H. E. Gregory, J. M. Clarke, and E. O. Hovey, C. W. Hayes being absent, met the Organizing Committee of the Paleontological Society, consisting of Charles Schuchert, chairman, and Messrs. F. B. Loomis, David White, and T. W. Stanton. Messrs. S. W. Williston and H. F. Osborn of the Paleontological Committee were absent. The conferees went over the proposed constitution of the new society article by article, and finally adopted it in the form which was distributed to the Fellows of the Society in March, 1909, and which is appended to this report. (See pages 77-82 of this volume.)

As organized, the Paleontological Society is a section of the Geological Society of America, in accordance with the expressed wish of the majority of paleontologists of the country, and only Fellows of the Geological Society are eligible to Fellowship in the Paleontological Society. Fellows of the Geological Society whose work is primarily in paleontology may become Fellows of the Paleontological Society, on application to the Council of the latter, without further payment of dues. Persons not Fellows of the Geological Society who are engaged or interested in paleontological work may become members of the Paleontological Society by vote of the Society on nomination by two Fellows and approved by the Council.

In order to perfect the affiliation of the new society with the parent organization, certain changes in the Constitution and By-Laws of the Geological Society of America must be made. They are as follows:

Insert Article VIII (new): "SECTIONS. Any group of Fellows representing a particular branch of geology may, with consent of the Council, organize as a section of the Society, with separate constitution and by-laws, provided that nothing in such constitution and by-laws conflicts with the Constitution and By-Laws of the Geological Society of America, in letter or spirit, and provided that such constitution and by-laws and all amendments thereto shall have been approved by the Council."

Change the number of the present Article VIII to IX.

Add to Chapter IV, paragraph 1, this sentence: "One of the nominees for vice-president shall be the nominee for president of the Paleontological Society which has been organized as a section under Article VIII of the Constitution."

PUBLIC LIBRARY,
No. 550.6 G4
DETROIT, MICH.

This committee having been given power at the Baltimore meeting to act for the Society, the report was, on motion, received and approved.

REPORT OF THE PUBLICATION COMMITTEE

The Publication Committee, through its chairman, E. O. Hovey, then, on call of Vice-President Adams, reported as follows for the information of the Society:

The replies which were received to the circular issued in 1908 regarding editorial usage were carefully compiled and considered, and the following recommendations were made to and adopted by the Council at a meeting held October 14, 1909, at the American Museum of Natural History:

1. That the usage of the Bulletin as to spelling, abbreviation, and punctuation be continued, except that the period be used after all abbreviations, including "Dr." and "Mr.," and that the abbreviation "Jr." and "Sr." be used in place of "Junior" and "Senior" when applied to the name of an individual, and the entire avoidance of the word "Esquire" in connection with the name of an American.

2. Under the head of "capitalization" the adoption of the forms exemplified as follows, although this may lead to some inconsistencies: Lake Superior, Blue Lake, Potomac River, Atlantic Ocean, Mount Taylor, Mount Taylor Range, New York City, Great Neck, Rocky Mountains, Devil's Tower, Summit County, cretacic or Cretaceous.

3. Use of "Cretaceous" and "Carboniferous" and the like, unless the author desires to commit himself to the forms ending in "ic."

4. That authors be allowed to follow the system of capitalization and spelling generally followed as the usage of their particular branches of science.

5. Printing and sending out to the Fellowship simple directions for the preparation of manuscript, which shall embody the preference of the Council as to editorial usage, illustrated with typical examples.

In accordance with the fifth recommendation, the following suggestions for the preparation of manuscripts have been prepared:

The Society's requirements as to the form in which manuscripts should be submitted are so clearly exemplified in the Bulletin itself that it seems almost superfluous to make any suggestions. The following brief summary, however, is offered for the assistance of authors, in accordance with the order employed in the form of publication adopted by the Society.

Title of paper.—The title of a paper should be as brief as is consistent with giving a proper understanding of the subject treated.

It is never necessary to rewrite a paper in the title, and elaborateness rarely adds sufficiently to clearness to warrant its use.

The employment of articles before the title should be avoided.

Name of the author.—Following the title, but in a separate line, should appear the name of the author, preceded by the word "By."

Presentation before the Society.—The next line should state whether the paper was "Read before the Society," "Presented extemporaneously," "Presented in abstract," or "Presented by title before the Society," being careful to add the date of reading or presentation.

Contents.—A table of contents must be prepared by the author, showing the order in which the subject-matter of the paper has been treated. Such a table of contents is the test of the logical preparation and presentation of a paper.

Captions.—The Society has adopted four captions, the first of which is centrally placed and printed in capitals and small capitals; the second is in italicised capitals centrally placed; the third is a side or paragraph heading printed in italics, and the fourth is a side heading in Roman type.

Under each of the first three headings there should be at least two headings of the next order of inferiority to warrant the use of the latter. For instance, authors will frequently use a superior heading and then under it place only one inferior heading. Manifestly, these two should be combined in one caption appropriately referring to the next which follows.

Footnotes.—Consecutive Arabic numerals should be used for the indication of footnotes, beginning with "1," and the footnote should be inserted wherever it may come on the typewritten page, with a ruled or dotted line immediately above and below it.

Illustrations.—Two classes of illustrations are employed in the Bulletin—text figures and half-tone plates. The former are numbered from 1 upward in each brochure, so that the numbering adopted by the author is not disturbed. The latter, however, have consecutive numbering for the entire volume; hence an author should give each plate a tentative designation, such as A, B, C. This designation will be replaced by the correct plate number and the author given an opportunity to verify references. The plates are made up of one or more figures. When more than one figure occurs on the page the first is designated "Figure 1," followed by the appropriate title; the second "Figure 2," etcetera. In addition to this, the plate has a general title or plate title descriptive of all the figures. An exception is made sometimes in the matter of titling plate figures, when there are many illustrations to the page, as in plates of fossils. In such cases a full description of the figures is usually printed on a separate page facing the plate, all such plates being placed at the end of the brochure. As all the text figures and all plates are scheduled in the "preliminary matter" which precedes each volume, the desirability of making captions as brief as is consistent with clearness is apparent.

More comprehensive suggestions, which meet the general approval of the Society's Council, are contained in the "Suggestions to Authors," compiled for the United States Geological Survey by George McLane Wood. A copy of this pamphlet has been sent to every Fellow of the Geological Society of America, and careful study of its recommendations is urged on all those preparing papers to be offered for publication in the Bulletin.

Papers should always be submitted in typewriting.

On motion, the report was ordered printed in full.

The committee reports further that the Council, at the meeting of October 14, 1909, voted to change the manner of issuing the Bulletin to quarterly form, beginning March, 1910, with Part I of Volume XXI, doing away with both the brochure form and the collated volume, except that author's separates of the different memoirs will be issued like the former brochures, thirty of which will be given gratis to authors, as here-

tofore, and a supply will be retained by the Secretary to meet the demand for single articles. The change to a quarterly issue has been made to facilitate publication and to take advantage of entry in the post-office as second-class matter, thereby effecting a material saving in the expense of distribution.

AMENDMENTS TO THE CONSTITUTION AND BY-LAWS

The Secretary then announced that more than three-fourths of the Fellows of the Society had voted in favor of the amendments to the Constitution which had been proposed in due form in March, 1909, and that they therefore were operative. They are those referred to in the report of the Committee on the Formation of the Paleontological Society and are as follows:

Insert Article VIII (new): "SECTIONS. Any group of Fellows representing a particular branch of geology may, with consent of the Council, organize as a section of the Society with separate constitution and by-laws, provided that nothing in such constitution and by-laws conflicts with the Constitution and By-Laws of the Geological Society of America, in letter or spirit, and provided that such constitution and by-laws and all amendments thereto shall have been approved by the Council."

Change the number of the present Article VIII to IX.

Vice-President Adams then called for a vote on the amendment to the By-Laws, which had been proposed in due form in the Secretary's March circular, as follows:

Add to Chapter IV, paragraph 1, this sentence: "One of the nominees for vice-president shall be the nominee for president of the Paleontological Society which has been organized as a section under Article VIII of the Constitution."

On motion, this amendment was unanimously adopted.

REPORT OF THE PHOTOGRAPH COMMITTEE

A report from the Photograph Committee was then called for, but was not presented on account of the absence of N. H. Darton, who constitutes the committee.[5]

[5] Since the close of the meeting the report has been transmitted to the Secretary, and is as follows:

TWENTIETH ANNUAL REPORT OF THE COMMITTEE ON PHOTOGRAPHS

During the year 1909 there has been no change in the collection of photographs belonging to the Society. No new views have been offered. Several members have inspected the collection, and ordered prints from negatives belonging to the United States Geological Survey.

The collection is stored in a chest and bundle in my office in the building of the Geological Survey at Washington, where it can be readily consulted.

Respectfully submitted.

N. H. DARTON,
Committee.

Announcements regarding the arrangements effected by the Local Committee were then made by the Secretary.

TITLES OF PAPERS AND NAMES OF DISPUTANTS

The general business of the morning having been finished, the program of scientific papers relating to glaciology and physiography was taken up as follows:

POST-TERTIARY HISTORY OF THE LAKES OF ASIA MINOR AND SYRIA

BY ELLSWORTH HUNTINGTON

Presented extemporarily; illustrated with lantern slides; 25 minutes. Discussed by W. M. Davis, F. P. Gulliver, A. W. Grabau, D. W. Johnson, and Joseph Barrell, with reply by the author.

TIDE-WATER GLACIERS OF PRINCE WILLIAM SOUND AND KENAI PENINSULA, ALASKA

BY U. S. GRANT

In the absence of the author, the paper was read by title.

OSCILLATIONS OF ALASKAN GLACIERS

BY R. S. TARR AND LAWRENCE MARTIN

Presented extemporarily by the junior author; illustrated with lantern slides; 20 minutes. Discussed by François E. Matthes.

SOME EFFECTS OF GLACIER ACTION IN ICELAND

BY FRED E. WRIGHT

Read from manuscript; 15 minutes. Discussed by W. M. Davis.

CLIFF SCULPTURE OF THE YOSEMITE VALLEY

BY FRANÇOIS E. MATTHES[6]

Read in part from manuscript and in part presented extemporarily with lantern slide illustrations; 30 minutes.

EOLATION UNDER THE STIMULUS OF ARIDITY

BY CHARLES R. KEYES

Read by title in the absence of the author.

At 12.30 o'clock p. m. the Society adjourned for luncheon at the Colonial Club, convening again at 2.30 p. m. in two sections for the reading of

[6] Introduced by M. R. Campbell.

papers. The glacial and physiographic papers were continued under the temporary chairmanship of H. L. Fairchild, F. B. Taylor acting as secretary of the section.

FURTHER LIGHT ON THE GORGE OF THE HUDSON

BY JAMES F. KEMP

Given extemporaneously; illustrated with drawings; 20 minutes. The paper was discussed by J. W. Spencer, with reply by the author.

RICHMOND BOULDER TRAINS

BY F. B. TAYLOR

Presented extemporaneously; illustrated with lantern slides; 15 minutes.

GLACIAL LAKES AND CHANNELS NEAR SYRACUSE

BY T. C. HOPKINS

Read by title, the author being absent.

SHORELINES OF THE GLACIAL LAKES IN THE OBERLIN QUADRANGLE, OHIO

BY FRANK CARNEY

Given extemporarily; illustrated with map and lantern slides; 15 minutes.

ISOBASES OF THE ALGONQUIN AND IROQUOIS BEACHES AND THEIR SIGNIFICANCE

BY JAMES WALTER GOLDTHWAIT[7]

Read from manuscript; illustrated with lantern slides; 20 minutes. The paper was discussed by J. W. Spencer, Frank Carney, and F. B. Taylor. Reply was made by the author.

GLACIAL INVESTIGATIONS IN THE LAKE SUPERIOR REGION IN 1909

BY FRANK LEVERETT

Read by title in the absence of the author.

DIVERSION OF THE MONTREAL RIVER

BY ROBERT BELL

Presented extemporaneously and illustrated with a map; 25 minutes.

[7] Introduced by F. B. Taylor.

RELATIVE WORK OF THE TWO FALLS OF NIAGARA

BY J. W. SPENCER

Given extemporarily; 20 minutes.

At 5 o'clock the section adjourned.

The main division of the Society met, under the chairmanship of Vice-President Adams, Tuesday afternoon, in the Nash Botanical Lecture Room of the Museum, and began the consideration of the papers in physical and structural geology.

NATURAL BRIDGES OF NORTH AMERICA, WITH A DISCUSSION OF THEIR ORIGIN

BY HERDMAN F. CLELAND

Presented extemporaneously; illustrated with lantern slides; 20 minutes. Discussed by H. C. Hovey and J. W. Spencer.

GEOLOGICAL SUGGESTIONS DERIVED FROM A NEW ARRANGEMENT OF THE ELEMENTS

BY B. K. EMERSON

Given extemporaneously; illustrated with diagrams; 30 minutes.

NEW LIGHT ON THE GEOLOGY OF THE WASATCH MOUNTAINS

BY ELIOT BLACKWELDER

Presented extemporaneously; illustrated with lantern slides; 35 minutes. Discussed by S. F. Emmons, Bailey Willis, A. W. Grabau, Arthur Keith, and the author.

HAWAIIAN VOLCANOES

BY REGINALD A. DALY

Presented without notes; illustrated with lantern slides; 25 minutes. Discussed by T. A. Jaggar, Jr.

The main section adjourned at 5 o'clock.

Tuesday evening the Society met in the rooms of the Technology Union and participated in a smoker as the guests of the Department of Geology of the Massachusetts Institute of Technology. The attendance was large and the occasion was most enjoyable.

SESSION OF WEDNESDAY, DECEMBER 29

Wednesday morning the Society was called to order in the Geological Lecture Hall at 9.45 o'clock by Vice-President Adams.

REPORT OF THE AUDITING COMMITTEE

The report of the Auditing Committee being called for, it was presented by F. L. Ransome, to the effect that the Treasurer's accounts had been examined and found to be correctly cast and properly vouched, and that the committee would visit Baltimore at an early date and verify the securities in the custody of the Treasurer.[8]

On motion, the report was accepted.

TITLES OF PAPERS AND NAMES OF DISPUTANTS

After sundry announcements had been made by the Secretary, the reading of papers was resumed, and the audience listened to

GENETIC CLASSIFICATION OF ACTIVE VOLCANOES

BY T. A. JAGGAR, JR.

which was read from manuscript, occupying 20 minutes. This was followed by

TARUMAI, A CUMULO-VOLCANIC ERUPTION IN JAPAN, 1909

BY T. A. JAGGAR, JR.

Given without notes; illustrated with lantern slides; 15 minutes. The discussion of the two papers was participated in by E. O. Hovey, W. M. Davis, F. L. Ransome, R. A. Daly, Bailey Willis, F. E. Wright, Ernest Howe, and the author.

ALASKAN EARTHQUAKE OF 1899

BY LAWRENCE MARTIN

Presented extemporaneously; illustrated with lantern slides; 10 minutes.

STRUCTURE OF THE NORTHERN PORTION OF THE BURNING SPRINGS, VOLCANO ANTICLINE, IN PLEASANTS, WOOD, AND RITCHIE COUNTIES, WEST VIRGINIA

BY F. G. CLAPP

Read from manuscript; 10 minutes. Discussed by I. C. White.

[8] Since the close of the meeting the committee has reported to the Secretary that Messrs. Ransome and Emmons visited Baltimore, according to instructions from the Society, and found the securities in the possession of the Treasurer to correspond with the list reported by him.

GENERALIZED SECTION THROUGH THE APPALACHIAN MOUNTAINS OF MARYLAND

BY CHARLES K. SWARTZ

Read from manuscript; illustrated with maps and sections. Discussed by Arthur Keith, A. H. Purdue, and the author.

The morning session adjourned at noon.

The afternoon meeting was in two parts, the main section continuing the consideration of the papers on physical and structural geology in the Geological Lecture Hall, while the second section met in the Mineralogical Laboratory, and proceeded with the reading of the papers on glacial and physiographic geology.

In the main section the following papers were called:

SOME INSTANCES OF FLOWING WELLS ON ANTICLINES

BY F. G. CLAPP

Read from manuscript; 10 minutes. Discussed by A. C. Lane.

LOCAL ANTICLINES IN THE CHAGRIN SHALES AT CLEVELAND, OHIO

BY FRANK R. VAN HORN

Presented extemporaneously and illustrated with lantern slides; 20 minutes. The paper was discussed by H. L. Fairchild.

President-elect Arnold Hague then took the chair, while a paper entitled "An experimental investigation into the flow of diabase" was presented extemporarily by F. D. Adams, with lantern slide illustrations, in 20 minutes. The paper was discussed by H. F. Reid, Bailey Willis, and the author.

Vice-President Adams resumed the chair, and the following paper was read by title in the absence of the author:

COON BUTTE AND METEORITIC FALLS OF THE DESERT

BY CHARLES R. KEYES

Then was presented extemporaneously

CONNATE WATERS OF THE ATLANTIC COAST

BY ALFRED C. LANE

occupying 20 minutes.

After this

CHANGES PRODUCED ON SPRINGS BY A SINKING WATER TABLE

BY T. C. HOPKINS

was given without notes; 10 minutes.

There was then read a paper entitled

CRITERIA FOR THE RECOGNITION OF VARIOUS TYPES OF SAND GRAINS

BY W. H. SHERZER

The reading was followed by the presentation of illustrative lantern slides; 20 minutes. The discussion that followed was participated in by Joseph Barrell, A. C. Lane, and W. M. Davis.

The next paper

CLIMATE AND PHYSICAL CONDITIONS OF THE KEEWATIN

BY A. P. COLEMAN

was presented without notes, in 20 minutes, and was discussed by W. G. Miller, H. F. Reid, W. M. Davis, and the author.

With permission from the Society, an overture from the American Philosophical Society was then read, asking for encouragement of a plan for American exploration in the Antarctic regions.

On motion, the communication was referred to the Council for consideration and report back to the Society.

Then was presented from notes

THEORY OF ISOSTACY

BY W. M. DAVIS

in 15 minutes. The paper was discussed by H. F. Reid.

The last paper of the afternoon was

MECHANICS OF FAULTS

BY HARRY FIELDING REID

Presented extemporaneously; 20 minutes.

The section adjourned at 5 o'clock.

The section of glacial and physiographic geology began the afternoon session with H. L. Fairchild in the chair and F. B. Taylor acting as secretary.

The first paper was

RELATIONSHIP OF NIAGARA RIVER TO THE GLACIAL PERIOD

BY J. W. SPENCER

Presented without notes; illustrated with lantern slides; 20 minutes. Discussed by Lawrence Martin, F. B. Taylor, W. M. Davis, and the author.

PARTIAL DRAINAGE OF NIAGARA FALLS IN FEBRUARY, 1909

BY J. W. SPENCER

Presented extemporaneously; illustrated with lantern slides; 10 minutes.

BIRD'S HILL: AN ESKER NEAR WINNIPEG, MANITOBA

BY WARREN UPHAM

Read by title in the absence of the author.

ORIGIN OF CLIFF LAKE, MONTANA

BY G. R. MANSFIELD[9]

Read from manuscript; illustrated with lantern slides; 20 minutes. Discussed by W. M. Davis and the author.

ROCK STREAMS OF VETA MOUNTAIN, COLORADO

BY H. B. PATTON

Presented extemporaneously; illustrated with lantern slides; 20 minutes. Discussed by D. W. Johnson, F. E. Matthes, W. M. Davis, and the author.

The next two papers were presented without notes. They were entitled

MEANDERS AND SCALLOPS

BY M. S. W. JEFFERSON

Illustrated with lantern slides; 15 minutes.

BEACH CUSPS

BY M. S. W. JEFFERSON

Fifteen minutes.

[9] Introduced by U. S. Grant.

They were followed by

BEACH CUSPS

BY D. W. JOHNSON

Given extemporaneously; illustrated with lantern slides; 20 minutes. The section adjourned at 5 o'clock.

Wednesday evening the Fellows of the Geological Society of America and of the Paleontological Society, the members of the latter and friends, in all 131 persons, took part in the customary annual dinner, which was held in the Hotel Vendome, Boston. The meeting was presided over by Vice-President Adams, who, before general speaking began, called upon President-elect Hague to read the following communication which had been received from President Gilbert:

"To the Fellows of the Geological Society of America I send a cordial greeting. Though physically separate, I am one with you in motive and enthusiasm.

"Keenly as I should enjoy the intellectual interchange and the social joys of our assemblage, keenly as I regret my inability to assume the duties properly joined to the high honor you have bestowed on me, yet am I not without consolation. For I know well that other hands, willing and able, will perform whatever I have left undone, that the lusty vigor of our Society ensures the quick closing of every gap, and that the cherished cause for which our association stands is imperiled by no default of an individual.

"As thought roams backward over the long series of our fruitful meetings, I realize as never before how the growth of our science has been interwoven with the growth of our organization, how our individual efficiency and our associative efficiency have each enhanced the other, and how the harmony and solidarity of our geologic body have been fostered by the personal contact of its members.

"As I dwell with longing on all the privileges that this week are yours, I realize more than ever before how strong are the personal ties which bind me to you and how large a measure of real comradeship has come to be implied by our formal title of Fellow. And so, Fellows of the Geological Society, I send a more than cordial—I send an affectionate greeting.

"G. K. GILBERT.

"WASHINGTON, *December* 26, 1909."

On motion of Second Vice-President Clarke, the Secretary was unanimously instructed to send the following telegraphic reply to Mr. Gilbert:

"29 DECEMBER, 1909.

"Mr. GROVE K. GILBERT, *Washington, D. C.:*

"We, Fellows of the Geological Society, assembled at the Annual Dinner, return your greeting and express our sincere regret at your absence. We assure you of our cordial personal interest and sympathy and of our hope to have you with us soon again.

"EDMUND OTIS HOVEY, *Secretary.*"

Then, after a graceful speech of welcome to the Society and guests, Doctor Adams called upon James F. Kemp to act as toastmaster. This service was rendered in a happy vein of humor that thoroughly satisfied the company, as one after another eight or ten Fellows responded to the summons of the toastmaster. The evening was further enlivened by occasional singing by the diners from a "Geological Song Book," which had been compiled and provided by A. C. Lane. A cordial letter was prepared, signed by all present and subsequently sent to Professor Eduard Suess, of Vienna, congratulating him on the completion of his monumental work "Das Antlitz der Erde."[10] C. H. Warren was the member of the Local Committee who had charge of the arrangement for the dinner.

Session of Thursday, December 30

Thursday morning the Society was called to order in general session at 9.45 o'clock by Vice-President Adams, in the Geological Lecture Hall of the University Museum. The printed report of the Council, which had just arrived, was distributed, but action upon it was deferred to the afternoon.

Resolution concerning Antarctic research

The Secretary then reported that the Council had considered with approval the preamble and resolutions submitted by the American Philosophical Society, and recommended their adoption. They are as follows:

"Whereas the United States in former years did much to increase our knowledge of the Antarctic regions, by means of the expedition of Lieut. Charles Wilkes, U. S. N., and the voyages of American whalers, and

"Whereas there has been a great revival of interest in recent years in the South Polar regions, resulting in the dispatching of scientific expeditions to explore portions of this area by England, Belgium, Sweden, Germany, and France, and

[10] The following reply to this communication has been received by the Secertary:

VIENNA, *March* 4, 1910.

DEAR SIR: I am indeed at a loss in trying to describe the feeling which pervaded me in receiving the testimonial letter and congratulation of the Geological Society of America. If my book possesses some merit, it consists in showing how very narrow the limits of our actual knowledge of the earth are, and if anything is apt to bid glad hopes, it is the brilliant list of one hundred and ten great masters and ardent scholars trying to unravel the structure of your vast and diversified country, who have honored me in this extraordinary way.

I beg to transmit my heartfelt thanks to all these gentlemen and colleagues in science and my respectful compliments to President Gilbert.

Your deeply obliged,

E. SUESS.

"Whereas large areas in the far South will remain unexplored and many branches of science would be benefited by the sending of an American expedition to the far South, having for its object the re-exploration of Wilkes Land and the collection of scientific data relating to regions visited, therefore be it

"*Resolved*, That the Geological Society of America respectfully urges the Federal Government to consider the desirability of appropriating funds for the purpose of fitting out a suitable vessel, under the direction of the Secretary of the Navy, to undertake such exploration."

On motion, the resolution was passed.

REPORT OF THE COMMITTEE ON GEOLOGIC NOMENCLATURE

The Committee on Geologic Nomenclature then reported, through Arthur Keith, its secretary, that requests for suggestions had been sent out early in the year and some replies received, but that no questions had been submitted to the consideration of the committee. On motion, the report was received and the committee continued.

REPORT OF THE COMMITTEE ON THE NOMENCLATURE OF FAULTS

The Committee on the Nomenclature of Faults reported, through its chairman, H. F. Reid, that correspondence had been carried on with the Geological Society of London and other bodies, with not wholly satisfactory results, but that the work was progressing. On motion, the report was received and the committee continued.

TITLES OF PAPERS AND NAMES OF DISPUTANTS

The paper entitled

A PROGRESS GEOLOGIC MAP OF OKLAHOMA

BY C. N. GOULD

was then presented extemporarily, illustrated with a large map; 15 minutes. It was discussed by Arthur Keith.

The next paper was read from manuscript. It was

SALT MARSH FORMATION NEAR BOSTON AND ITS GEOLOGICAL SIGNIFICANCE

BY CHARLES A. DAVIS[11]

Twenty minutes. Remarks were made by A. W. Grabau.

Then was presented from notes and illustrated with lantern slides a paper entitled

OBSERVATIONS ON RATE OF SEA CLIFF EROSION

BY CHARLES P. BERKEY

Fifteen minutes.

[11] Introduced by David White.

The Society then divided again into two parts, the stratigraphic and paleontologic section remaining in the large lecture hall, while the main body went into the laboratory of the Department of Mineralogy. The chairman of the section was President-elect Hague, while the Secretary, during the presentation of the first four papers, was H. B. Kümmel, and afterwards C. N. Gould.

In the absence of the author, the paper entitled

RED SANDSTONES OF SOUTHEASTERN MINNESOTA

BY C. W. HALL

was read by title.

Then

PERMO-CARBONIC CONGLOMERATES OF SOUTH BRAZIL

BY J. B. WOODWORTH

was presented extemporaneously from notes, illustrated with lantern slides; 45 minutes. Discussed by Bailey Willis and I. C. White.

Adjourned at noon for luncheon, and reconvened at 2.30 o'clock p. m.

MAGOTHY FORMATION OF THE ATLANTIC COAST

BY A. B. BIBBINS

was read by title, the author being absent.

After this

AGE OF THE "CALCIFEROUS" FORMATIONS OF THE MOHAWK VALLEY

BY E. O. ULRICH AND H. P. CUSHING

was given extemporaneously by Professor Cushing; 15 minutes.

The paper entitled

UPPER CAYUGAN OF MARYLAND

BY T. POOLE MAYNARD[12]

was then read from manuscript; 15 minutes. Discussed by A. W. Grabau.

[12] Introduced by W. B. Clark.

Then the paper

STRATIGRAPHIC RELATIONS OF THE LIVINGSTON BEDS OF CENTRAL MONTANA

BY R. W. STONE AND W. B. CALVERT[13]

was read from manuscript by Mr. Stone; 30 minutes.

After this the following papers were read by title in the absence of their authors:

DISCOVERY OF FOSSILS IN THE QUANTICO SLATE BELT AND THE ASSOCIATION OF VOLCANO-SEDIMENTARY BEDS WITH THE SLATES OF THE VIRGINIA CRYSTALLINE REGIONS

BY T. L. WATSON AND S. L. POWELL

PLEISTOCENE PHENOMENA OF CENTRAL MASSACHUSETTS

BY W. C. ALDEN

REVISION OF PALEOZOIC SYSTEMS, II

BY E. O. ULRICH

EVIDENCE THAT THE FOSSILIFEROUS GRAVEL AND SAND BEDS OF IOWA AND NEBRASKA ARE AFTONIAN

BY B. SHIMEK

NOTE ON A METHOD IN TEACHING OPTICAL MINERALOGY

BY F. W. MC NAIR[14]

PEBBLES: TYPES FORMED BY THE SEA, RIVERS, WIND, AND GLACIERS

BY F. P. GULLIVER

RHODE ISLAND COAL

BY CHARLES W. BROWN

PREGLACIAL DRAINAGE OF CENTRAL WESTERN NEW YORK

BY A. W. GRABAU

At 4 o'clock the section adjourned.

After the separation into sections the main body of the Society, under the chairmanship of Vice-President Adams, listened to the papers in the

[13] Introduced by M. R. Campbell.
[14] Introduced by Alfred C. Lane.

petrologic, mineralogic, and economic subdivision of the program, the first paper being read from manuscript. It was

GEOLOGIC THERMOMETRY

BY FRED E. WRIGHT

Fifteen minutes. Remarks upon the paper were made by J. F. Kemp, R. A. Daly, A. C. Lane, and E. T. Wherry.

Then was presented extemporaneously

SOME MINERAL RELATIONS FROM THE LABORATORY VIEWPOINT

BY ARTHUR L. DAY

Twenty minutes. Discussion was postponed to the afternoon session, and the Society adjourned at 12.15 for luncheon, convening again at 2 o'clock, when the discussion of Doctor Day's paper was taken up and participated in by A. C. Gill, Whitman Cross, and the author.

After this

ORIGIN OF THE ALKALINE ROCKS

BY REGINALD A. DALY

was read in abstract from the complete manuscript, 25 minutes, and was discussed by J. F. Kemp, Whitman Cross, H. P. Cushing, A. E. Barlow, W. G. Miller, and the author.

Then was presented extemporaneously

THE COMPLEX OF ALKALINE IGNEOUS ROCKS AT CUTTINGSVILLE, VERMONT

BY J. W. EGGLESTON[15]

illustrated with diagrams and specimens. The paper was discussed by J. E. Wolff, F. E. Wright, and J. A. Dresser.

The next paper

OBSIDIAN FROM HRAFNTINNUHRYGGUR, ICELAND

BY FRED E. WRIGHT

was given without notes, and was illustrated with a suite of specimens; 5 minutes.

[15] Introduced by J. E. Wolff.

Following this, the paper entitled

BLEACHING OF GRANITE AT LIMESTONE CONTACTS

BY H. P. CUSHING

was presented extemporarily, illustrated with specimens; 15 minutes.

Then the joint paper

PEGMATITE IN THE GRANITE OF QUINCY, MASSACHUSETTS

BY C. H. WARREN AND C. PALACHE

was divided into two parts, the discussion of the petrography being read from manuscript by Professor Warren, while the mineralogical portion was presented extemporaneously by Professor Palache, using a large series of specimens as illustrations. Remarks were made by J. F. Kemp.

BARITE DEPOSITS OF FIVE ISLANDS, NOVA SCOTIA

BY CHARLES H. WARREN

was presented by title.

FAYALITE IN THE GRANITE OF ROCKPORT, MASSACHUSETTS

BY CHARLES PALACHE

was given without manuscript, and consisted of an exhibition of specimens with a description of their mode of occurrence; 10 minutes.

NELSONITE: A NEW ROCK TYPE, ITS OCCURRENCE, ASSOCIATION, AND COMPOSITION

BY T. L. WATSON AND S. TABER

was read by title in the absence of the authors.

MICROSCOPIC STUDY OF CERTAIN COALS IN RELATION TO THE SAPROPELIC HYPOTHESIS

BY E. C. JEFFREY[16]

was presented extemporaneously with numerous lantern slide illustrations, 30 minutes. Remarks on the paper were made by David White.

REGIONAL DEVOLATILIZATION OF COAL

BY DAVID WHITE

was given without manuscript, 15 minutes, and was discussed by J. F. Kemp.

[16] Introduced by David White.

The last paper on the program was

PRESENT AND FUTURE OF NATURAL GAS FIELDS IN THE NORTHERN APPALACHIANS

BY F. G. CLAPP

which was read from manuscript, 20 minutes, and was discussed by J. F. Kemp and F. R. Van Horn.

After the presentation of Professor Jeffrey's paper the scientific program was interrupted for the consideration of some matters of business. The Council report was taken from the table, and on motion was accepted and ordered printed. It will be found on pages 35-39 of this volume.

Whitman Cross then offered a vote of thanks to the Governing Board of Harvard University for the courtesies of the University Museum and to the geologists and mineralogists of Harvard University and the Massachusetts Institute of Technology for the completeness of the arrangements made for the meetings. The motion was seconded by James F. Kemp, and was heartily passed by the Society.

Sessions of the Paleontological Section, December 29, 30, and 31

The section of the Geological Society of America which had been organized under section VIII of the Constitution as amended in 1909 met in the Nast Lecture Hall of the Harvard University Museum on Wednesday, Thursday, and Friday, December 29-31, 1909, with John M. Clarke as President and H. F. Cleland as Secretary. An account of the meeting will be found on pages 69-76 of this volume.

Cordilleran Section

In accordance with a request received from the Council of the Cordilleran Section, the General Council voted that the sectional meeting might be postponed from convocation week to the latter part of February or March.

Report of the Council

To the Geological Society of America,
in Twenty-second Annual Meeting assembled:

The regular annual meeting of the Council was held at Baltimore, Maryland, in connection with the meeting of the Society, December 29, 1908, to January 1, 1909. An adjourned meeting was held in New York city on October 14, 1909, and some business has been transacted by correspondence.

The details of administration for the twenty-first year of the existence of the Society are given in the following reports of the officers:

Secretary's Report

To the Council of the Geological Society of America:

Meetings.—The proceedings of the annual meeting of the Society held at Baltimore, Maryland, December 29, 1908, to January 1, 1909, have been recorded in the closing brochure of volume 20 of the Bulletin, which is now in press.

Membership.—During the past year the Society has lost two Fellows by death, Persifor Frazer and Daniel W. Langton, and one member has been dropped on account of non-payment of dues. The names of the fourteen Fellows elected at the Baltimore meeting have been added to the list, all of them having completed their membership according to rule. The present enrollment of the Society is 305. Twenty-four candidates are before the Society for election, and several applications are under consideration by Council.

Distribution of Bulletin.—There have now been distributed 9 brochures, comprising 356 pages, of volume 20, and the remaining brochures, including the Proceedings, are in the hands of the printers in various stages of completion. By action of the Publication Committee no manuscripts were accepted by the Secretary after October 1.

There are now 95 regular subscribers for the Bulletin and 75 institutions that receive the publication on exchange.

The irregular distribution of the Bulletin during the past year has been as follows: Complete volumes, sold to the public, including one complete set, 30; sent out to supply delinquents, 12; sent out to supply deficiencies, 4; brochures sent out to supply deficiencies and delinquents, 189; sold to Fellows, 15; sold to the public, 48. Three copies of volume 19 have been bound for the use of the officers and the library.

Bulletin Sales.—The receipts from the sale of the Bulletin during the past year are shown in the following table:

Bulletin Sales, December 1, 1908, to November 30, 1909

	Complete volumes.			Brochures.			Grand total.
	Fellows.	Public.	Total.	Fellows.	Public.	Total.	
Volume 1	.....	$7.50	$7.50	$0.25	$7.05	$7.30	$14.80
Volume 2	.....	15.00	15.00	.25	.40	.65	15.65
Volume 3	.....	15.00	15 00	.....	.45	.45	15.45
Volume 4	.....	7.50	7.50	.....	4.40	4.40	11.90
Volume 5	.....	7.50	7.50	.20	1.30	1.50	9.00
Volume 6	.....	7.50	7.50	.35	.75	1.10	8.60
Volume 7	4.00	7.50	11.50	.55	.....	.55	12.05
Volume 8	4.00	7.50	11.50	.....	.35	.35	11.85
Volume 9	.....	7.50	7.50	1.25	.35	1.60	9.10
Volume 10	4.00	7.50	11.50	1.70	2.10	3.80	15.30
Volume 11	.....	7.50	7.50	2.45	.....	2.45	9.95
Volume 12	.....	7.50	7.50	1.50	.55	2.05	9.55
Volume 13	.....	7.50	7.50	1.20	.....	1.20	8.70
Volume 14	.....	7.50	7.50	.....	.....	.....	7.50
Volume 15	.....	7.50	7.50	1.50	.55	2.05	9.55
Volume 16	.....	7.50	7.50	2.20	2.20	4.40	11.90
Volume 17	.....	7.50	7.50	3.80	3.60	7.40	14.90
Volume 18	.....	27.50	27.50	1.75	12.95	14.70	42.20
Volume 19	5.00	165.00	170.00	4.52	3.40	7.92	177.92
Volume 20	.....	480.00	480.00	.....	7.20	7.20	487.20
Volume 21	.....	37.50	37.50	.....	.....	.....	37.50
	$17.00	$852.50	$869.50	$23.47	$47.60	$71.07	$940.57
Balance on 1908 report							.05
Collection charges added to checks							.52
							$941.14

Receipts for the fiscal year	$940.62
Previously reported	11,245.51
Total receipts to date	$12,186.13
Charged, but not yet received:	
On 1909 account	28.80
Total sales to date	$12,214.93

The bills for volume 20 have not been sent out to volume subscribers who do not pay in advance, and the table given above includes only actual payments.

The cost of publishing the Bulletin, volumes 1–19, has been $35,296.10, the average cost per volume being $1,857.69. These figures, however, do not include the expense of distribution. The expense of publication has increased so much during the past few years that the price of the Bulletin to libraries and foreign individuals has been raised to $7.50 per volume by vote of Council.

Expenses.—The following table gives the cost of administration and of Bulletin distribution during the past year:

EXPENDITURE OF SECRETARY'S OFFICE DURING THE FISCAL YEAR ENDING NOVEMBER 30, 1909

Account of Administration

Postage and telegrams	$49.13	
Express	4.43	
Stationery and printing	181.70	
Addressograph plates	.72	
Stenographer at 1908 meeting	150.00	
Lantern operator at 1908 meeting	6.00	
Labor and materials	9.15	
Binding	3.50	
Expenses of Cordilleran Section	7.97	
Expenses of Paleontological Society	56.83	
Total		$469.43

Account of Bulletin

Postage	$132.39	
Express	39.20	
Collection on checks	1.50	
Labor and materials	1.05	
Stationery and printing	21.95	
Binding	1.00	
Total		$197.09
Total expenses for the year		$666.52

Respectfully submitted.

EDMUND OTIS HOVEY,
Secretary.

NEW YORK, *December 15, 1909.*

TREASURER'S REPORT

To the Council of the Geological Society of America:

The Treasurer herewith submits his annual report for the year ending December 1, 1909:

Eight (8) Fellows, Charles Schuchert, H. V. Winchell, Earle Sloan, Eliot Blackwelder, H. E. Gregory, G. B. Richardson, Ralph Arnold, and Edward B. Mathews, have commuted for life during the year by the payment of one hundred dollars each, thus increasing the total Life Commutations to ninety-three (93), which with four (4) Honorary

Life Members, makes a total of ninety-seven (97), of whom eighty-eight (88) are now living.

Two (2) Fellows are delinquent for four years, one (1) Fellow is delinquent for three years, two (2) Fellows are delinquent for two years, and are therefore liable to be dropped from the roll for non-payment of dues, in accordance with section 3, chapter 1, of the By-Laws; twelve (12) Fellows are delinquent for the present year.

The membership of the Society, including delinquents, aggregates at the present time 305, of whom 88 have commuted for life. There have been two deaths and one member has been dropped for non-payment of dues.

RECEIPTS

Balance in treasury December 1, 1909			$795.83
Fellowship fees 1906 (3)	$30.00		
" " 1907 (10)	100.00		
" " 1908 (24)	240.00		
" " 1909 (198)	1,980.00		
		2,350.00	
Initiation fees (14)		140.00	
Life commutations (8)		800.00	
Interest on investments:			
Iowa Apartment House Company	$60.00		
Ontario Apartment House Company	200.00		
Texas and Pacific Railroad bonds	100.00		
United States Steel Corporation bonds	150.00		
St. Louis, Iron Mountain and Southern Railroad bonds	50.00		
Interest on deposits in Baltimore Trust and Guarantee Co	27.01		
		587.01	
Received from Secretary:			
Sales of publications		940.62	
Subscriptions toward publication of papers:			
J. C. Branner		50.00	
Charles Schuchert		59.77	
Authors' corrections (paid by authors)		2.10	
Collection charges added to checks		.52	
Stenographer's report (paid by A. A. A. S.)		54.80	
Collection charges added to checks		.40	
Received from J. C. Merriam (afterward refunded)		70.00	
			$5,851.05

EXPENDITURES

Secretary's office:			
Administration	$412.60		
Bulletin	197.09		
Paleontological Society	56.83		
Secretary's allowance	500.00		
		$1,166.52	
Treasurer's office:			
Postage, bond, safe deposit, etcetera	$40.75		
Treasurer's allowance for clerical hire	50.00		
		90.75	
Librarian's office		10.00	
Publication of Bulletin:			
Printing	$1,951.94		
Engraving	477.04		
Editor's allowance	250 00		
		2,678.98	
Refunded to J. C. Merriam		70.00	
			$4,016.25
Balance on hand December 1, 1909, in bank			1,834.80
			$5,851.05

Respectfully submitted,

WM. BULLOCK CLARK,
Treasurer.

BALTIMORE, MD., *December 1, 1909.*

EDITOR'S REPORT

To the Council of the Geological Society of America:

Owing to the condition of publication of volume 20, it is not possible for the Editor to furnish to the Council the usual data. All papers are in type and the proceedings of the Baltimore meeting are in the hands of the printer. A full statement will be included in the next Report of the Council.

J. STANLEY-BROWN,
Editor.

COLD SPRING HARBOR, LONG ISLAND,
December 20, 1909.

Register of the Boston-Cambridge Meeting, 1909

The following Fellows were in attendance at the meeting:

Frank Dawson Adams
Alfred Ernest Barlow
Joseph Barrell
George H. Barton
Florence Bascom
Ray Smith Bassler
Joshua W. Beede
Robert Bell
Charles P. Berkey
Samuel Walker Beyer
Eliot Blackwelder
John Adams Bownocker
Albert Perry Brigham
Reginald W. Brock
Charles Wilson Brown
Frank Carney
T. C. Chamberlin
Frederick G. Clapp
William Bullock Clark
John Mason Clarke
Herdman F. Cleland
Arthur P. Coleman
Whitman Cross
Henry P. Cushing
Reginald A. Daly
William M. Davis
Richard E. Dodge
John Alexander Dresser
Charles R. Eastman
Benjamin K. Emerson
Samuel F. Emmons
Herman L. Fairchild
August F. Foerste
Adam Capen Gill
Charles Newton Gould
Amadeus W. Grabau
Herbert E. Gregory
Frederic P. Gulliver
Arnold Hague
Christopher W. Hall
Thomas C. Hopkins
Edmund Otis Hovey
Horace C. Hovey
Ernest Howe
Ellsworth Huntington
John D. Irving
Robert T. Jackson
Thomas A. Jaggar, Jr.
Mark S. W. Jefferson
Albert Johannsen
Douglas Wilson Johnson
Arthur Keith
James F. Kemp
Henry B. Kümmel
Alfred C. Lane
William McInnes
Curtis F. Marbut
Benjamin L. Miller
Willet G. Miller
Ida Helen Ogilvie
Henry F. Osborn
Charles Palache
Horace B. Patton
Frederick B. Peck
Richard A. F. Penrose, Jr.
George H. Perkins
Albert Homer Purdue
Frederick Leslie Ransome
Harry Fielding Reid
William North Rice
Charles H. Richardson
George Burr Richardson
Heinrich Ries
Rudolph Ruedemann

THOMAS EDMUND SAVAGE
CHARLES SCHUCHERT
WILL H. SHERZER
WILLIAM JOHN SINCLAIR
GEORGE OTIS SMITH
J. W. SPENCER
TIMOTHY WILLIAM STANTON
CHARLES KEPHART SWARTZ
FRANK B. TAYLOR
EDWARD O. ULRICH
FRANK ROBERTSON VAN HORN
THOMAS WAYLAND VAUGHAN
THOMAS L. WALKER
CHARLES H. WARREN
DAVID WHITE
ISRAEL C. WHITE
HENRY S. WILLIAMS
BAILEY WILLIS
SAMUEL W. WILLISTON
ALFRED W. G. WILSON
JOHN E. WOLFF
JAY B. WOODWORTH
FREDERIC E. WRIGHT

Fellows-elect

WALLACE WALTER ATWOOD
EDSON SUNDERLAND BASTIN
EDWARD WILBER BERRY
ARTHUR LOUIS DAY
FRANK WALBRIDGE DE WOLF
JAMES WALTER GOLDTHWAIT
BAIRD HALBERSTADT
FREDERIC BREWSTER LOOMIS
RICHARD SWANN LULL
GEORGE ROGERS MANSFIELD
LAWRENCE MARTIN
WILLIAM JOHN MILLER
PHILIP S. SMITH

In addition, many visitors attended the sessions.

CONSTITUTION AND BY-LAWS

REFERENCES TO ADOPTION AND CHANGES

The provisional Constitution under which the Society was organized was approved August 15, 1888, and adopted December 27, 1888 (see Bulletin, volume 1, pages 7-8). These rules were elaborated and the revised Constitution and By-Laws were adopted December 27, 1889 (volume 1, pages 536, 571–578).

Several minor changes have been made in these rules, which are on record in the Bulletin as follows: Changes in the Constitution: December, 1894, volume 6, page 432; December, 1897, volume 9, page 400; December, 1909, volume 21, page 19. Changes in the By-Laws: December, 1891, volume 3, page 470; December, 1893, volume 5, pages 553-554; December, 1894, volume 6, page 432; December, 1903, volume 14, page 535; December, 1909, volume 21, page 19.

CONSTITUTION

ARTICLE I

NAME

This Society shall be known as THE GEOLOGICAL SOCIETY OF AMERICA.

ARTICLE II

OBJECT

The object of this Society shall be the promotion of the Science of Geology in North America.

ARTICLE III

MEMBERSHIP

The Society shall be composed of Fellows, Correspondents, and Patrons.

1. Fellows shall be persons who are engaged in geological work or in teaching geology.

Fellows admitted without election under the provisional Constitution shall be designated as Original Fellows on all lists or catalogues of the Society.

2. Correspondents shall be persons distinguished for their attainments in Geological Science and not resident in North America.

3. Patrons shall be persons who have bestowed important favors upon the Society.

4. Fellows alone shall be entitled to vote or hold office in the Society.

ARTICLE IV

OFFICERS

1. The Officers of the Society shall consist of a President, First and Second Vice-Presidents, a Secretary, a Treasurer, an Editor, and six Councilors.

These officers shall constitute an Executive Committee, which shall be called the Council.

2. The President shall discharge the usual duties of a presiding officer at all meetings of the Society and of the Council. He shall take cognizance of the acts of the Society and of its officers, and cause the provisions of the Constitution and By-Laws to be faithfully carried into effect.

3. The first Vice-President shall assume the duties of President in case of the absence or disability of the latter. The Second Vice-President shall assume the duties of President in case of the absence or disability of both the President and First Vice-President.

4. The Secretary shall keep the records of the proceedings of the Society, and a complete list of the Fellows, with the dates of their election and disconnection with the Society. He shall also be the secretary of the Council.

The Secretary shall coöperate with the President in attention to the ordinary affairs of the Society. He shall attend to the preparation, printing and mailing of circulars, blanks and notifications of elections and meetings. He shall superintend other printing ordered by the Society or by the President, and shall have charge of its distribution, under the direction of the Council.

The Secretary, unless other provision be made, shall also act as Editor of the publications of the Society, and as Librarian and Custodian of the property.

5. The Treasurer shall have the custody of all funds of the Society. He shall keep account of receipts and disbursements in detail, and this shall be audited as hereinafter provided.

6. The Editor shall supervise all matters connected with the publication of the transactions of the Society under the direction of the Council.

7. The Council is clothed with executive authority and with the legislative powers of the Society in the intervals between its meetings; but no extraordinary act of the Council shall remain in force beyond the next following stated meeting without ratification by the Society. The Council shall have control of the publications of the Society, under provisions of the By-Laws and of resolutions from time to time adopted. They shall receive nominations for Fellows, and, on approval by them, shall submit such nominations to the Society for action. They shall have power to fill vacancies *ad interim* in any of the offices of the Society.

8. *Terms of office.*—The President and Vice-Presidents shall be elected annually, and shall not be eligible to re-election more than once until after an interval of three years after retiring from office.

The Secretary, Treasurer, and Editor shall be eligible to re-election without limitation.

The term of office of the Councilors shall be three years; and these officers shall be so grouped that two shall be elected and two retire each year. Councilors retired shall not be re-eligible till after the expiration of a year.

Article V

Voting and Elections

1. All elections shall be by ballot. To elect a Fellow, Correspondent or Patron, or impose any special tax, shall require the assent of nine-tenths of all Fellows voting.

2. Voting by letter may be allowed.

3. *Election of Fellows.*—Nominations for fellowship may be made by two Fellows according to a form to be provided by the Council. One of these Fel-

lows must be personally acquainted with the nominee and his qualifications for membership. The Council will submit the nominations received by them, if approved, to a vote of the Society in the manner provided in the By-Laws. The result may be announced at any stated meeting; after which notice shall be sent out to Fellows elect.

4. *Election of officers.*—Nominations for office shall be made by the Council. The nominations shall be submitted to a vote of the Society in the same manner as nominations for fellowship. The results shall be announced at the Annual Meeting; and the officers thus elected shall enter upon duty at the adjournment of the meeting.

Article VI

MEETINGS

1. The Society shall hold at least one stated meeting a year, in the winter season. The date and place of the Winter Meeting shall be fixed by the Council, and announced each year within three months after the adjournment of the preceding Winter Meeting. The program of each meeting shall be determined by the Council, and announced beforehand, in its general features. The details of the daily sessions shall also be arranged by the Council.

2. The Winter Meeting shall be regarded as the Annual Meeting. At this, elections of officers shall be declared, and the officers elect shall enter upon duty at the adjournment of the meeting.

3. Special meetings may be called by the Council, and must be called upon the written request of twenty Fellows.

4. Stated meetings of the Council shall be held coincidently with the stated meetings of the Society. Special meetings may be called by the President at such times as he may deem necessary.

5. *Quorum.*—At meetings of the Society a majority of those registered in attendance shall constitute a quorum. Five shall constitute a quorum of the Council.

Article VII

PUBLICATION

The serial publications of the Society shall be under the immediate control of the Council.

Article VIII

SECTIONS

Any group of Fellows representing a particular branch of geology may, with consent of the Council, organize as a section of the Society with separate constitution and by-laws, provided that nothing in such constitution and by-laws conflict with the constitution and by-laws of the Geological Society of America, in letter or spirit, and provided that such constitution and by-laws and all amendments thereto shall have been approved by the Council.

Article IX

AMENDMENTS

1. This Constitution may be amended at any annual meeting by a three-fourths vote of all the Fellows, provided that the proposed amendment shall have been submitted in print to all Fellows at least three months previous to the meeting.

2. By-laws may be made or amended by a majority vote of the Fellows present and voting at any annual meeting, provided that printed notice of the proposed amendment or by-law shall have been given to all Fellows at least three months before the meeting.

BY-LAWS

Chapter I

OF MEMBERSHIP

1. No person shall be accepted as a Fellow unless he pay his initiation fee, and the dues for the year, within three months after notification of his election. The initiation fee shall be ten (10) dollars and the annual dues ten (10) dollars, the latter payable on or before the annual meeting in advance; but a single prepayment of one hundred (100) dollars shall be accepted as commutation for life.

2. The sums paid in commutation of dues shall be covered into the Publication Fund.

3. An arrearage in payment of annual dues shall deprive a Fellow of the privilege of taking part in the management of the Society and of receiving the publications of the Society. An arrearage continuing over two (2) years shall be construed as notification of withdrawal.

4. Any person eligible under Article III of the Constitution may be elected Patron upon the payment of one thousand (1,000) dollars to the Publication Fund of the Society.

Chapter II

OF OFFICIALS

1. The President shall countersign, if he approves, all duly authorized accounts and orders drawn on the Treasurer for the disbursement of money.

2. The Secretary, until otherwise ordered by the Society, shall perform the duties of Editor, Librarian, and Custodian of the property of the Society.

3. The Society may elect an Assistant Secretary.

4. The Treasurer shall give bonds, with two good sureties approved by the Council, in the sum of five thousand dollars, for the faithful and honest performance of his duties and the safe-keeping of the funds of the Society. He may deposit the funds in bank at his discretion, but shall not invest them without authority of the Council. His accounts shall be balanced as on the thirtieth day of November of each year.

5. In the selection of Councilors the various sections of North America shall be represented as far as practicable.

6. The minutes of the proceedings of the Council shall be subject to call by the Society.

7. The Council may transact its business by correspondence during the intervals between its stated meetings; but affirmative action by a majority of the Council shall be necessary in order to make action by correspondence valid.

CHAPTER III

OF ELECTION OF MEMBERS

1. Nominations for fellowship may be proposed at any time on blanks to be supplied by the Secretary.

2. The *form* for the nomination of Fellows shall be as follows:

In accordance with his desire, we respectfully nominate for Fellow of the Geological Society of America:

Full name; degrees; address; occupation; branch of Geology now engaged in, work already done and publications made.

(Signed by at least two Fellows.)

The form when filled is to be transmitted to the Secretary.

3. The Secretary will bring all nominations before the Council, and the Council will signify its approval or disapproval of each.

4. At least a month before one of the stated meetings of the Society the Secretary will mail a printed list of all approved nominees to each Fellow, accompanied by such information as may be necessary for intelligent voting; but an informal list of the candidates shall be sent to each Fellow at least two weeks prior to distribution of the ballots.

5. The Fellows receiving the list will signify their approval or disapproval of each nominee, and return the lists to the Secretary.

6. At the next stated meeting of the Council the Secretary will present the lists and the Council will canvass the returns.

7. The Council, by unanimous vote of the members in attendance, may still exercise the power of rejection of any nominee whom new information shows to be unsuitable for fellowship.

8. At the next stated meeting of the Society the Council shall declare the results.

9. Correspondents and Patrons shall be nominated by the Council, and shall be elected in the same manner as Fellows.

CHAPTER IV

OF ELECTION OF OFFICERS

1. The Council shall prepare a list of nominations for the several offices, which list will constitute the regular ticket. The ticket must be approved by a majority of the entire Council. The nominee for President shall not be a member of the Council. One of the nominees for vice-president shall be the nominee for the presidency of the Paleontological Society which has been organized as a section under Article VIII of the Constitution.

2. The list shall be mailed to the Fellows, for their information, at least nine months before the Annual Meeting. Any five Fellows may forward to the Secretary other nominations for any or all offices. All such nominations reaching the Secretary at least 40 days before the Annual Meeting shall be printed, together with the names of the nominators, as special tickets. The regular and special tickets shall then be mailed to the Fellows at least 25 days before the Annual Meeting.

3. The Fellows will send their ballots to the Secretary in double envelopes, the outer envelope bearing the voter's name. At the Winter Meeting of the

Council, the Secretary will bring the returns of ballots before the Council for canvass, and during the Winter Meeting of the Society the Council shall declare the result.

4. In case a majority of all the ballots shall not have been cast for any candidate for any office, the Society shall by ballot at such Winter Meeting proceed to make an election for such office from the two candidates having the highest number of votes.

CHAPTER V

OF FINANCIAL METHODS

1. No pecuniary obligation shall be contracted without express sanction of the Society or the Council. But it is to be understood that all ordinary, incidental, and running expenses have the permanent sanction of the Society, without special action.

2. The creditor of the Society must present to the Treasurer a fully itemized bill, certified by the official ordering it, and approved by the President. The Treasurer shall then pay the amount out of any funds not otherwise appropriated, and the receipted bill shall be held as his voucher.

3. At each annual meeting, the President shall call upon the Society to choose two Fellows, not members of the Council, to whom shall be referred the books of the Treasurer, duly posted and balanced to the close of November thirtieth, as specified in the By-Laws, Chapter II, clause 4. The Auditors shall examine the accounts and vouchers of the Treasurer, and any member or members of the Council may be present during the examination. The report of the Auditors shall be rendered to the Society before the adjournment of the meeting, and the Society shall take appropriate action.

CHAPTER VI

OF PUBLICATIONS

1. The publications are in charge of the Council and under its control.

2. One copy of each publication shall be sent to each Fellow, Correspondent, and Patron, and each author shall receive thirty (30) copies of his memoir.

CHAPTER VII

OF THE PUBLICATION FUND

1. The Publication Fund shall consist of donations made in aid of publication, and of the sums paid in commutation of dues, according to the By-Laws, Chapter I, clause 2.

2. Donors to this fund, not Fellows of the Society, in the sum of two hundred dollars, shall be entitled, without charge, to the publications subsequently appearing.

CHAPTER VIII

OF ORDER OF BUSINESS

1. The Order of Business at Winter Meetings shall be as follows:

(1) Call to order by the presiding officer.

(2) Introductory ceremonies.

(3) Report of the Council (including report of the officers).
(4) Appointment of the Auditing Committee.
(5) Declaration of the vote for officers, and election by the meeting in case of failure to elect by the Society through transmitted ballots.
(6) Declaration of the vote for Fellows.
(7) Deferred business.
(8) New business.
(9) Announcements.
(10) Necrology.
(11) Reading of scientific papers.

2. At an adjourned session the order shall be resumed at the place reached on the previous adjournment, but new business will be in order before the reading of scientific papers.

3. At the Summer Meeting the items of business under numbers (3), (4), (5), (10) shall be omitted.

4. At any Special Meeting the order of business shall be numbers (1), (2), (3), (9), followed by the special business for which the meeting was called.

PUBLICATION RULES OF THE GEOLOGICAL SOCIETY OF AMERICA

(Adopted by the Council April 21, 1891; Revised April 30, 1894, May, 1904, and February 5, 1910)

General Provisions

Section 1. The Council shall annually appoint from their own number a Publication Committee, consisting of the Secretary, the Treasurer, the Editor, and two others, whose duties shall be to determine the disposition of matter offered for publication, except as provided in section 12; to determine the expediency, in view of the financial condition of the Society, of publishing any matter accepted on its merits; to exercise general oversight of the matter and manner of publication; to determine the share of the cost of publication (including illustrations) to be borne by the author when it becomes necessary to divide cost between the Society and the author; to adjudicate any questions relating to publication that may be raised from time to time by the Editor or by the Fellows of the Society; and in general to act for the Council in all matters pertaining to publication. (Cons., Art. IV, 7; Art. VII; By-Laws, chap. VI.)

2. The duties of the Editor are to receive material offered for publication; to examine and submit it, with estimates of cost, to the Publication Committee; to publish all material accepted by the Council or Publication Committee; to revise proofs in connection with authors; to prepare lists of contents and general indexes; to audit bills for printing and illustrating; and to perform all other duties connected with publication not assigned to other officers. (Cons., Art. IV, 6; Rules, Sec. 16.)

3. The duties of the Secretary include the preparation of a record of the proceedings of each meeting of the Society in form for publication, and the custody, distribution, sale, exchange or other authorized disposition of the publications. (Cons., Art. IV, 4; By-Laws, chap. II, 2.)

4. Special committees may be appointed by the Council or the Publication Committee to examine and report on any matter offered for publication. (Rules, Sec. 11.)

The Bulletin

Title and general character

5. The Society shall publish a serial record of its work entitled "Bulletin of the Geological Society of America."

6. The Bulletin shall be published in quarterly parts, consecutively paged for each volume. The parts shall be suitably designated and each shall bear a title setting forth the contents and authorship, the seal and imprint of the Society and the date of publication.

7. The closing quarterly part of each volume shall contain an index, paged consecutively with the body of the volume; and it shall be accompanied by a volume title-page and lists of contents and illustrations, together with lists of

the publications of the Society and such other matter as the Publication Committee may deem necessary, all arranged under Roman pagination.

MATTER OF THE BULLETIN

8. The matter published in the Bulletin shall comprise (1) communications presented at meetings by title or otherwise; (2) communications or memoirs not presented before the Society; (3) abstracts of papers read before the Society, prepared or revised for publication by authors; (4) reports of discussions held before the Society, prepared or revised for publication by authors; (5) proceedings of the meetings of the Society prepared by the Secretary; (6) plates, maps, and other illustrations necessary for the proper understanding of communications; (7) lists of Officers and Fellows, Constitution, By-Laws, resolutions of permanent character, rules relating to procedure, to publication, and to other matters, etcetera, and (8) indexes, title-pages, and lists of contents for each volume.

9. Abstracts, reports of discussion, or other matter purporting to emanate from any author shall not be published unless prepared or revised by the author.

10. Manuscript designed for publication in the Bulletin must be complete as to copy for text and illustration, except by special arrangement between the author and the Council or Publication Committee; it must be perfectly legible (preferably typewritten) and preceded by a table of contents (section 20). The cost of necessary revision of copy or reconstruction of illustrations shall be assessed on the author.

11. The Editor shall examine matter designated for publication, and shall prepare an itemized estimate of the cost of publication and convey the whole to the Publication Committee. The Publication Committee shall then scrutinize the communication with reference, first, to relevancy; second, to scientific value; third, to literary character, and, fourth, to cost of publication, including revision. For advice with reference to the relevancy, scientific value, and literary character of any communication the Publication Committee may refer it to a special committee of their own number or of the Society at large or may call to their aid from outside one or more experts. Questions of disagreement between the Editor and authors shall be referred to the Publication Committee, and appeal may be taken to the Council.

12. Communications from non-fellows shall be published only by specific authority from the Council.

13. Communications from Fellows not presented at regular meetings of the Society shall be published only upon unanimous vote of the Publication Committee, except by specific authority from the Council.

14. Matter offered for publication becomes thereby the property of the Society, and shall not be published elsewhere prior to publication in the Bulletin, except by consent of the Publication Committee.

DETAILS OF THE BULLETIN

15. The matter of each memoir shall be classified by subjects, and the classification suitably indicated by subtitles; and a list of contents shall be arranged; and such memoir may, at the option of the Publication Committee, contain an alphabetical index, provided the author prepare and pay for it.

16. Proofs of text and illustrations shall be submitted to authors whenever practicable; but printing shall not be delayed by reason of absence or incapacity of authors more than one week beyond the time required for transmission by mail. Complete proofs of the proceedings of meetings shall be sent to the Secretary, and proofs of papers and abstracts contained therein and exceeding one-half page in length shall be sent also to authors.

17. The cost of proof corrections in excess of five per cent on the cost of printing may be charged to authors.

18. Unless the author of a memoir objects thereto, the discussion upon his communication shall be printed at the end thereof, with a suitable reference in the list of contents. In case the author objects to this arrangement, the discussion shall be printed in the closing number of the volume.

19. The author of each memoir occupying eight pages or more of text in the body of the Bulletin shall receive 30 "separates" without charge, and may order through the Editor any edition of exactly similar separates at an advance of ten per cent. on the cost of paper, presswork and binding; and no author's separates of such memoirs shall be issued except in this regular form.

20. Authors of papers, abstracts, or discussions less than eight printed pages in length may order, through the Editor, at an advance of ten per cent. on the cost of paper, presswork, binding and necessary composition, any number of extra copies, provided they bear the original pagination and a printed reference to the serial and volume from which they are extracted.

21. The Editor shall keep a record of all publications issued wholly or in part under the auspices of the Society, whether the same be author's editions of memoirs, author's extracts from proceedings, or any other matter printed from type originally composed for the Bulletin.

DIRECTIONS TO PRINTER

22. Each memoir of the Bulletin shall begin, under its proper title, on an odd-numbered page bearing at its head the title of the serial, the volume number, the part number, the limiting pages, the plates, and the date of publication, together with a list of contents. Each memoir shall be accompanied by the illustrations pertaining to it, the plates numbered consecutively for the volume.

23. The author's separates of each memoir shall be enclosed in a cover bearing at the head of its title-page the title of the serial, the volume number, the limiting pages, and the numbers of the contained plates; in its upper-central part a title indicating the contents and authorship; in its lower-central part the seal of the Society; and at the bottom the imprint of the Society. (See also Sections 19 and 20.)

24. The bottom of each signature and each initial page will bear a signature mark giving an abbreviated title of the serial, the volume, and the year; and every page (except volume title-page) shall be numbered, the initial and subtitle pages in parentheses at bottom.

25. The page-head titles shall be: on even-numbered pages, name of author and catch title of paper; on odd-numbered pages, catch title to contents of page.

26. The date of publication of each brochure shall be the day upon which the last form is locked and put on the press.

27. The type used in printing the Bulletin shall be as follows: For memoirs, body, long primer, 6-to-pica leads; extracts, brevier, 8-to-pica leads; footnotes, nonpareil, set solid; titles, long primer caps, with small caps for author's name; subtitles, long primer caps, small caps, italic, etcetera, as far as practicable; for designation of cuts, nonpareil caps and italics, and for legends, nonpareil, Roman, set solid; for lists of contents of brochures, brevier, 6-to-pica leads, a new line to an entry, running indentation; for volumes, the same, except 4-to-pica leads and names of authors in small caps; for indexes, nonpareil, set solid, double column, leaders, catch words in small caps, with spaces between initial letters. For serial titles, on initial pages, brevier block caps, with corresponding small caps for volume designation, etcetera; on covers, the same, except for page heads long primer caps; for serial designation, long primer; for brochure designation, pica caps; special title and author's name, etcetera, long primer and brevier caps; no frame on cover. No change in type shall be made to adjust matter to pages.

28. Volumes, plates, and cuts in text shall be numbered in Arabic; Roman numeration shall be used only in signature marks, and in paging the lists of contents, etcetera, arranged for binding at the beginning of the volume.

29. Imprimatur of Editor, on volume title-page; imprimatur of Council and Publication Committee, on obverse of volume title-page; imprimatur of Secretary, on initial pages and covers of brochures of proceedings. Printer's card, in fine type on obverse of title-page.

30. The paper shall be for body of volume, 70-pound toned paper, folding to 16 x 25 centimeters; for plates, good quality plate paper, smooth-surfaced, white, cut to 6½ x 10 inches for single plates; for covers smooth-surfaced, fine quality 70-pound light-buff manila paper.

31. The sheets of the brochures shall be stitched with thread; single page plates shall be stitched with the sheets of the brochure; folding plates may be either gummed or stitched (mounted on stubs if necessary); covers shall be gummed.

EDITION, DISTRIBUTION, AND PRICE

32. The regular edition shall be 545 copies in the regular quarterly form and 40 copies separately in covers of each memoir occupying eight pages or more of text. Each author shall receive 30 copies of his memoir gratis. If two or more authors contribute to a memoir brochure of eight pages or more in length, the edition shall be enlarged so as to give each author 30 copies. (By-Laws, chap. VI, 2.)

33. The undistributed residue of separates shall be held for sale.

34. The Bulletin shall be sent free to Fellows of the Society not in arrears for dues more than one year, and also to exchanging institutions. (By-Laws, chap. I, 3.)

35. The price of the Bulletin shall be as follows: To Fellows, libraries, and institutions, and to individuals not residing in North America, $7.50 per volume; to individuals residing in North America and who are not Fellows, $10. The price of each brochure shall be a multiple of five cents, and shall be, to Fellows, an advance on cost of about 100 per cent. and to the public an advance on cost of about 200 per cent. The prices of the separate brochures may be found in the front of each volume.

OFFICERS, CORRESPONDENTS, AND FELLOWS OF THE GEOLOGICAL SOCIETY OF AMERICA

OFFICERS FOR 1910

President:

ARNOLD HAGUE, Washington, D. C.

Vice-Presidents:

CHARLES SCHUCHERT, New Haven, Conn.
A. P. LOW, Ottawa, Ont.

Secretary:

EDMUND OTIS HOVEY, American Museum of Natural History, New York, N. Y.

Treasurer:

WM. BULLOCK CLARK, Baltimore, Maryland

Editor:

J. STANLEY-BROWN, Cold Spring Harbor, Long Island, N. Y.

Librarian:

H. P. CUSHING, Cleveland, Ohio

Councilors:

(Term expires 1910)

H. P. CUSHING, Cleveland, Ohio
H. B. PATTON, Golden, Colorado

(Term expires 1911)

GEO. OTIS SMITH, Washington, D. C.
HENRY S. WASHINGTON, Locust, New Jersey

(Term expires 1912)

J. B. WOODWORTH, Cambridge, Mass.
C. S. PROSSER, Columbus, Ohio.

MEMBERS, DECEMBER 31, 1909

CORRESPONDENTS

CHARLES BARROIS, D. ès Sc., D. Sc., Lille, France. Professor of Geology at the University. December, 1909.

W. C. BRÖGGER, Sc. D., LL. D., Christiania, Norway. Professor of Geology and Mineralogy at the Royal University. December, 1909.

SIR ARCHIBALD GEIKIE, D. C. L., Sc. D., LL. D., Hasslemere, England. President of the Royal Society, late Director General of the Geological Society of the United Kingdom. December, 1909.

ALBRECHT HEIM, D. Sc., Zürich, Switzerland. President of the Swiss Geological Commission and Professor of Geology at the University. December, 1909.

EMANUEL KAYSER, Ph. D., Marburg, Germany. Professor of Geology at the University. December, 1909.

EDUARD SUESS, Ph. D., Vienna, Austria. Formerly Professor of Geology at the Imperial Royal University, President of the Imperial Academy of Sciences. December, 1909.

FERDINAND ZIRKEL, D. Sc., Ph. D., Königstrasse 27, Bonn, Germany. Geheimer Rath, Professor (retired) of Mineralogy and Geology at the University of Leipzig. December, 1909.

FELLOWS

***Indicates Original Fellow (see article III of Constitution)**

CLEVELAND ABBE, JR., Ph. D., U. S. Weather Bureau, Washington, D. C. August, 1899.

FRANK DAWSON ADAMS, Ph. D., Montreal, Canada; Professor of Geology in McGill University. December, 1889.

GEORGE I. ADAMS, Sc. D., Bureau of Mines, Manila, P. I. December, 1902.

JOSÉ GUADALUPE AGUILERA, Ph. D., City of Mexico, Mexico; Director del Instituto Geologico de Mexico. August, 1896.

TRUMAN H. ALDRICH, M. E., 1739 P St. N. W., Washington, D. C. May, 1889.

HENRY M. AMI, A. M., Ottawa, Canada; Assistant Paleontologist on Geological and Natural History Survey of Canada. December, 1889.

FRANK M. ANDERSON, B. A., M. S., 2604 Ætna Street, Berkeley, Cal. California State Mining Bureau. June, 1902.

PHILIP ARGALL, 728 Majestic Building, Denver, Colo. August, 1896.

RALPH ARNOLD, Ph. D., 726 H. W. Hellman Bldg., Los Angeles, Cal. December, 1904.

GEORGE HALL ASHLEY, M. E., Ph. D., Washington, D. C.; U. S. Geological Survey. August, 1895.

RUFUS MATHER BAGG, JR., Ph. D., 603 W. Green St., Urbana, Ill.; Instructor in Geology in University of Illinois. December, 1896.

HARRY FOSTER BAIN, M. S., 667 Howard St., San Francisco, Cal. December, 1895.

S. PRENTISS BALDWIN, 736 Prospect St., Cleveland, Ohio. August, 1895.

SYDNEY H. BALL, A. B., 71 Broadway, New York City. December, 1905.

ERWIN HINCKLEY BARBOUR, Ph. D., Lincoln, Neb.; Professor of Geology, University of Nebraska, and Acting State Geologist. December, 1896.

ALFRED ERNEST BARLOW, B. A., M. A., D. Sc., 24 Durochen St., Montreal, Canada. December, 1906.

JOSEPH BARRELL, Ph. D., New Haven, Conn.; Professor of Structural Geology, Yale University. December, 1902.

GEORGE H. BARTON, B. S., Boston, Mass.; Curator, Boston Society of Natural History. August, 1890.

FLORENCE BASCOM, Ph. D., Bryn Mawr, Pa.; Professor of Geology, Bryn Mawr College. August, 1894.

RAY SMITH BASSLER, B. A., M. S., Ph. D., Washington, D. C.; U. S. National Museum. December, 1906.

WILLIAM S. BAYLEY, Ph. D., Urbana, Ill.; Assistant Professor of Geology, University of Illinois. December, 1888.

*GEORGE F. BECKER, Ph. D., Washington, D. C.; U. S. Geological Survey.

JOSHUA W. BEEDE, Ph. D., Bloomington, Ind.; Instructor in Geology, Indiana University. December, 1902.

ROBERT BELL, I. S. O., Sc. D., M. D., LL. D., F. R. S., Ottawa, Canada; Chief Geologist, Geological Survey, Department of Mines. May, 1889.

CHARLES P. BERKEY, Ph. D., New York City; Instructor in Geology, Columbia University. August, 1901.

SAMUEL WALKER BEYER, Ph. D., Ames, Iowa; Assistant Professor in Geology, Iowa Agricultural College. December, 1896.

ARTHUR B. BIBBINS, Ph. B., Baltimore, Md.; Instructor in Geology, Woman's College. December, 1903.

ALBERT S. BICKMORE, Ph. D., 863 Seventh Ave., New York City; Curator Emeritus, Department of Public Instruction, American Museum of Natural History. December, 1889.

IRVING P. BISHOP, 109 Norwood Ave., Buffalo, N. Y.; Professor of Natural Science, State Normal and Training School. December, 1899.

ELLIOT BLACKWELDER, A. B., Madison, Wis.; Assistant Professor of Geology in University of Wisconsin. December, 1908.

WILLIAM PHIPPS BLAKE, Ph. B., Tucson, Arizona; Director School of Mines, Arizona, and Territorial Geologist. December, 1908.

JOHN M. BOUTWELL, M. S., Washington, D. C.; Assistant Geologist, U. S. Geological Survey. December, 1905.

JOHN ADAMS BOWNOCKER, D. Sc., Columbus, Ohio; Professor of Inorganic Geology, Ohio State University. December, 1904.

*JOHN C. BRANNER, Ph. D., Stanford University, Cal.; Professor of Geology in Leland Stanford, Jr., University.

ALBERT PERRY BRIGHAM, A. B., A. M., Hamilton, N. Y.; Professor of Geology and Natural History, Colgate University. December, 1893.

REGINALD W. BROCK, M. A., Ottawa, Canada; Director, Geological Survey, Department of Mines. December, 1904.

ALFRED HULSE BROOKS, B. S., Washington, D. C.; Assistant Geologist, U. S. Geological Survey. August, 1899.

AMOS P. BROWN, Ph. D., Philadelphia, Pa.; Professor of Mineralogy and Geology, University of Pennsylvania. December, 1905.

CHARLES WILSON BROWN, Ph. D., A. M., Providence, R. I.; Assistant Professor and Head of the Department of Geology in Brown University. December, 1908.

ERNEST ROBERTSON BUCKLEY, Ph. D., Rolla, Mo. June, 1902.

*SAMUEL CALVIN, Ph. D., LL. D., Iowa City, Iowa; State Geologist; Professor of Geology in the State University of Iowa.

HENRY DONALD CAMPBELL, Ph. D., Lexington, Va.; Professor of Geology and Biology in Washington and Lee University. May, 1889.

MARIUS R. CAMPBELL, Washington, D. C.; U. S. Geological Survey. August, 1892.

FRANK CARNEY, A. B., Granville, Ohio; Professor of Geology in Denison University. December, 1908.

FRANKLIN R. CARPENTER, Ph. D., 1420 Josephine St., Denver, Colo. May, 1889.

ERMINE C. CASE, Ph. D., Ann Arbor, Mich.; Department of Geology, University of Michigan. December, 1901.

*T. C. CHAMBERLIN, LL. D., Chicago, Ill.; Head Professor of Geology, University of Chicago.

CLARENCE RAYMOND CLAGHORN, B. S., M. E., Tacoma, Wash. August, 1891.

FREDERICK G. CLAPP, S. B., 610 Fitzsimmons Bldg., Pittsburgh, Pa. Dec., 1905.

*WILLIAM BULLOCK CLARK, Ph. D., Baltimore, Md.; Professor of Geology in Johns Hopkins University; State Geologist.

JOHN MASON CLARKE, A. M., Ph. D., Albany, N. Y.; State Paleontologist. December, 1897.

HERDMAN F. CLELAND, Ph. D., Williamstown, Mass.; Professor of Geology, Williams College. December, 1905.

J. MORGAN CLEMENTS, Ph. D., Room 1707, 42 Broadway, New York City. December, 1894.

COLLIER COBB, A. B., A. M., Chapel Hill, N. C.; Professor of Geology in University of North Carolina. December, 1894.

ARTHUR P. COLEMAN, Ph. D., Toronto, Canada; Professor of Geology, Toronto University, and Geologist of Bureau of Mines of Ontario. December, 1896.

GEORGE L. COLLIE, Ph. D., Beloit, Wis.; Professor of Geology in Beloit College. December, 1897.

ARTHUR J. COLLIER, A. M., S. B., Washington, D. C.; Assistant Geologist, U. S. Geological Survey. June, 1902.

*THEODORE B. COMSTOCK, Sc. D., Los Angeles, Cal.

EUGENE COSTE, B. ès-Sc., E. M., Toronto, Canada. December, 1906.

*FRANCIS W. CRAGIN, Ph. D., Colorado Springs, Colo.; Professor of Geology in Colorado College.

ALJA ROBINSON CROOK, Ph. D., Springfield, Ill.; State Museum of Natural History. December, 1898.

*WILLIAM O. CROSBY, B. S., Boston, Mass.; Professor of Geology in Massachusetts Institute of Technology.

WHITMAN CROSS, Ph. D., Washington, D. C.; U. S. Geological Survey. May, 1889.

GARRY E. CULVER, A. M., 1104 Wisconsin St., Stevens Point, Wis. December, 1891.

EDGAR R. CUMINGS, Ph. D., Bloomington, Ind.; Professor of Geology, Indiana University. August, 1901.

*HENRY P. CUSHING, M. S., Ph. D., Adelbert College, Cleveland, Ohio; Professor of Geology, Western Reserve University.

REGINALD A. DALY, Ph. D., Boston, Mass.; Massachusetts Institute of Technology. December, 1905.

EDWARD SALISBURY DANA, A. B., A. M., Ph. D., 24 Hillhouse Ave., New Haven, Conn.; Professor of Physics and Curator of Mineralogical Collection in Yale University. December, 1908.

*NELSON H. DARTON, Washington, D. C.; U. S. Geological Survey.

*WILLIAM M. DAVIS, S. B., M. E., Cambridge, Mass.; Sturgis-Hooper Professor of Geology in Harvard University.

DAVID T. DAY, Ph. D., Washington, D. C.; U. S. Geological Survey. August, 1891.

ORVILLE A. DERBY, M. S., No. 80 Rua Visconde do Rio Branco, Sao Paulo, Brazil. December, 1890.

*JOSEPH S. DILLER, B. S., Washington, D. C.; U. S. Geological Survey.

EDWARD V. D'INVILLIERS, E. M., 506 Walnut St., Philadelphia, Pa. December, 1888.

RICHARD E. DODGE, A. M., New York City; Professor of Geography in Teachers' College. August, 1897.

NOAH FIELDS DRAKE, Ph. D., Tientsin, China; Professor of Geology in Imperial Tientsin University. December, 1898.

JOHN ALEXANDER DRESSER, B. A., M. A., Ottawa, Ontario, Canada. Geologist, Geological Survey of Canada. December, 1906.

CHARLES R. DRYER, M. A., M. D., Terre Haute, Ind.; Professor of Geography, Indiana State Normal School. August, 1897.

*EDWIN T. DUMBLE, 1306 Main St., Houston, Texas.

CLARENCE EDWARD DUTTON, A. B., Englewood, N. J.; Major, U. S. A. (retired). December, 1907.

ARTHUR S. EAKLE, Ph. D., Berkeley, Cal.; Instructor in Mineralogy, University of California. December, 1899.

CHARLES R. EASTMAN, A. M., Ph. D., Cambridge, Mass.; In Charge of Vertebrate Paleontology, Museum of Comparative Zoology, Harvard University. December, 1895.

EDWIN C. ECKEL, B. S., C. E., Munsey Building, Washington, D. C. December, 1905.

ARTHUR H. ELFTMAN, Ph. D., P. O. Box 601, Tonopah, Nevada. Dec., 1898.

*BENJAMIN K. EMERSON, Ph. D., Amherst, Mass.; Professor in Amherst College.

*SAMUEL F. EMMONS, A. M., E. M., Washington, D. C.; U. S. Geological Survey.

JOHN EYERMAN, F. Z. S., Oakhurst, Easton, Pa. August, 1891.

HAROLD W. FAIRBANKS, B. S., Berkeley, Cal.; Geologist State Mining Bureau. August, 1892.

*HERMAN L. FAIRCHILD, B. S., Rochester, N. Y.; Professor of Geology in University of Rochester.

OLIVER C. FARRINGTON, Ph. D., Chicago, Ill.; Curator of Geology, Field Museum of Natural History. December, 1895.

NEVIN M. FENNEMAN, Ph. D., Cincinnati, Ohio; Professor of Geology, University of Cincinnati. December, 1904.

CASSIUS ASA FISHER, A. B., A. M., 1832 Baltimore St. N. W., Washington, D. C.; U. S. Geological Survey. December, 1908.

AUGUST F. FOERSTE, Ph. D., 417 Grand Ave., Dayton, Ohio; Teacher of Sciences, Steele High School. December, 1899.

WILLIAM M. FONTAINE, A. M., Charlottesville, Va.; Professor of Natural History and Geology in University of Virginia. December, 1888.

MYRON LESLIE FULLER, S. B., 104 Belmont Ave., Brockton, Mass. December, 1898.

HENRY STEWART GANE, Ph. D., Santa Barbara, Cal. December, 1896.

HENRY GANNETT, S. B., A. Met. B., Washington, D. C.; U. S. Geological Survey. December, 1891.

RUSSELL D. GEORGE, A. B., A. M., Boulder, Colo.; Professor of Geology, University of Colorado. December, 1906.

*GROVE K. GILBERT, A. M., LL. D., Washington, D. C.; U. S. Geological Survey.

ADAM CAPEN GILL, Ph. D., Ithaca, N. Y.; Assistant Professor of Mineralogy and Petrography in Cornell University. December, 1888.

L. C. GLENN, Ph. D., Nashville, Tenn.; Professor of Geology in Vanderbilt University. June, 1900.

CHARLES H. GORDON, Ph. D., Knoxville, Tenn.; Professor of Geology and Mineralogy in the University of Tennessee. August, 1893.

CHARLES NEWTON GOULD, A. M., Norman, Okla.; Professor of Geology, University of Oklahoma. December, 1904.

AMADEUS W. GRABAU, S. M., S. D., New York City; Professor of Paleontology, Columbia University. December, 1898.

ULYSSES SHERMAN GRANT, Ph. D., Evanston, Ill.; Professor of Geology, Northwestern University. December, 1890.

HERBERT E. GREGORY, Ph. D., New Haven, Conn.; Silliman Professor of Geology, Yale University. August, 1901.

GEORGE P. GRIMSLEY, Ph. D., Martinsburg, W. Va.; Assistant State Geologist, Geological Survey of West Virginia. August, 1895.

LEON S. GRISWOLD, A. B., Rolla, Missouri. August, 1902.

FREDERIC P. GULLIVER, Ph. D., Norwichtown, Conn. August, 1895.

ARNOLD HAGUE, Ph. B., Washington, D. C.; U. S. Geological Survey. May, 1889.

*CHRISTOPHER W. HALL, A. M., 803 University Ave., Minneapolis, Minn.; Professor of Geology and Mineralogy in University of Minnesota.

GILBERT D. HARRIS, Ph. B., Ithaca, N. Y.; Assistant Professor of Paleontology and Stratigraphic Geology, Cornell University. December, 1903.

JOHN BURCHMORE HARRISON, M. A., F. I. C., F. G. S., Georgetown, British Guiana; Government Geologist. June, 1902.

JOHN B. HASTINGS, M. E., 1480 High St., Denver, Colo. May, 1889.

*ERASMUS HAWORTH, Ph. D., Lawrence, Kans.; Professor of Geology, University of Kansas.

C. WILLARD HAYES, Ph. D., Washington, D. C.; U. S. Geological Survey. May, 1889.

RICHARD R. HICE, B. S., Beaver, Pa. December, 1903.

*EUGENE W. HILGARD, Ph. D., LL. D., 2728 Bancroft Way, Berkeley, Cal.; Professor of Agriculture in University of California.

FRANK A. HILL, Roanoke, Va. May, 1889.

*ROBERT T. HILL, B. S., 25 Broad St., New York City.

RICHARD C. HILLS, Denver, Colo. August, 1894.

*Charles H. Hitchcock, Ph. D., LL. D., Honolulu, Hawaiian Islands; Professor Emeritus of Geology in Dartmouth College, Hanover, N. H.

William Herbert Hobbs, Ph. D., Ann Arbor, Mich.; Professor of Geology, University of Michigan; Assistant Geologist, U. S. Geological Survey. August, 1891.

*Levi Holbrook, A. M., P. O. Box 536, New York City.

Arthur Hollick, Ph. D., Bronx Park, New York City; Assistant Curator, Department of Fossil Botany, New York Botanical Garden. August, 1893.

*Joseph A. Holmes, Washington, D. C.; in charge of investigation of fuels and structural materials, U. S. Geological Survey.

Thomas C. Hopkins, Ph. D., Syracuse, N. Y.; Professor of Geology, Syracuse University. December, 1894.

*Edmund Otis Hovey, Ph. D., New York City; Curator of Geology and Invertebrate Paleontology, American Museum of Natural History.

*Horace C. Hovey, D. D., Newburyport, Mass.

Ernest Howe, Ph. D., 75 Kay St., Newport, R. I.; Assistant Geologist, U. S. Geological Survey. December, 1903.

*Edwin E. Howell, A. M., 612 Seventeenth St. N. W., Washington, D. C.

Lucius L. Hubbard, Ph. D., LL. D., Houghton, Mich. December, 1894.

Ellsworth Huntington, A. B., A. M., New Haven, Conn.; Instructor in Geography, Yale University. December, 1906.

Joseph P. Iddings, Ph. B., Chicago, Ill.; Professor of Petrographic Geology, University of Chicago. May, 1889.

John D. Irving, Ph. D., New Haven, Conn.; Professor of Economic Geology, Yale University. December, 1905.

A. Wendell Jackson, Ph. B., 432 Saint Nicholas Ave., New York City. December, 1888.

Robert T. Jackson, S. D., 9 Fayerweather St., Cambridge, Mass.; Assistant Professor in Paleontology in Harvard University. August, 1894.

Thomas M. Jackson, C. E., S. D., Clarksburg, W. Va. May, 1889.

Thomas Augustus Jaggar, Jr., A. B., A. M., Ph. D., Boston, Mass.; Professor of Geology, Massachusetts Institute of Technology. December, 1906.

Mark S. W. Jefferson, A. M., Ypsilanti, Mich.; Professor of Geography, Michigan State Normal College. December, 1904.

Albert Johannsen, B. S., Ph. D., Chicago, Ill.; Department of Geology, University of Chicago. December, 1908.

Douglas Wilson Johnson, B. S., Ph. D., Cambridge, Mass.; Assistant Professor of Physiography, Harvard University. December, 1906.

Alexis A. Julien, Ph. D., New York City; Curator (emeritus) in Geology in Columbia University. May, 1889.

George Frederick Kay, M. A., Iowa City, Iowa; Professor of Mineralogy, Petrography, and Economic Geology in State University of Iowa. December, 1908.

Arthur Keith, A. M., Washington, D. C.; U. S. Geological Survey. May, 1889.

*James F. Kemp, A. B., E. M., New York City; Professor of Geology in Columbia University.

Charles Rollin Keyes, Ph. D., 944 Fifth St., Des Moines, Iowa. August, 1890.

Edward M. Kindle, Ph. D., Washington, D. C.; Assistant Geologist, U. S. Geological Survey. December, 1905.

FRANK H. KNOWLTON, M. S., National Museum, Washington, D. C.; Assistant Paleontologist, U. S. Geological Survey. May, 1889.

EDWARD HENRY KRAUS, Ph. D., Ann Arbor, Mich.; Junior Professor of Mineralogy, University of Michigan. June, 1902.

HENRY B. KÜMMEL, Ph. D., Trenton, N. J.; State Geologist. December, 1895.

*GEORGE F. KUNZ, A. M. (Hon.), Ph. D. (Hon.), care of Tiffany & Co., Fifth Ave., at 37th St., New York City.

GEORGE EDGAR LADD, Ph. D., Rolla, Mo.; Director, School of Mines. August, 1891.

J. C. K. LAFLAMME, M. A., D. D., Quebec, Canada; Professor of Mineralogy and Geology in Laval University, Quebec. August, 1890.

HENRY LANDES, A. B., A. M., University Station, Seattle, Wash.; Professor of Geology in University of Washington. December, 1908.

ALFRED C. LANE, Ph. D., Tufts College, Mass.; Pearson Professor of Geology in Tufts College. December, 1889.

ANDREW C. LAWSON, Ph. D., Berkeley, Cal.; Professor of Geology and Mineralogy in the University of California. May, 1889.

WILLIS THOMAS LEE, M. S., Washington, D. C.; Assistant Geologist, U. S. Geological Survey. December, 1903.

CHARLES K. LEITH, Ph. D., Madison, Wis.; Professor of Geology, University of Wisconsin; Assistant Geologist, U. S. Geological Survey. December, 1902.

ARTHUR G. LEONARD, Ph. D., Grand Forks, N. Dak.; Professor of Geology and State Geologist, State University of North Dakota. December, 1901.

FRANK LEVERETT, B. S., Ann Arbor, Mich.; Geologist, U. S. Geological Survey. August, 1890.

JOSEPH VOLNEY LEWIS, B. E., S. B., New Brunswick, N. J.; Professor of Geology, Rutgers College. December, 1906.

WILLIAM LIBBEY, Sc. D., Princeton, N. J.; Professor of Physical Geography in Princeton University. August, 1899.

WALDEMAR LINDGREN, M. E., Washington, D. C.; U. S. Geological Survey. August, 1890.

GEORGE DAVIS LOUDERBACK, Ph. D., Berkeley, Cal.; Associate Professor of Geology, University of California. June, 1902.

ROBERT H. LOUGHRIDGE, Ph. D., Berkeley, Cal.; Assistant Professor of Agricultural Chemistry in University of California. May, 1889.

ALBERT P. LOW, B. A. Sc., LL. D., Ottawa, Canada; Deputy Minister, Department of Mines. December, 1905.

HIRAM DEYER MCCASKEY, B. S., Washington, D. C.; U. S. Geological Survey. December, 1904.

RICHARD G. MCCONNELL, A. B., Ottawa, Canada; Geologist on Geological and Natural History Survey of Canada. May, 1889.

JAMES RIEMAN MACFARLANE, A. B., 100 Diamond St., Pittsburg, Pa. August, 1891.

*W J MCGEE, LL. D., Washington, D. C.; Inland Waterways Commission.

WILLIAM MCINNES, A. B., Ottawa, Canada; Geologist, Geological and Natural History Survey of Canada. May, 1889.

PETER MCKELLAR, Fort William, Ontario, Canada. August, 1890.

CURTIS F. MARBUT, A. M., Columbia, Mo.; Professor of Geology in State University and Assistant on Missouri Geological Survey. August, 1897.

VERNON F. MARSTERS, A. M., Apartado 856, Lima, Peru. August, 1892.

GEORGE CURTIS MARTIN, Ph. D., Washington, D. C.; U. S. Geological Survey. June, 1902.

EDWARD B. MATHEWS, Ph. D., Baltimore, Md.; Professor of Mineralogy and Petrography in Johns Hopkins University. August, 1895.

W. D. MATTHEW, Ph. D., New York City; Associate Curator of Vertebrate Paleontology, American Museum of Natural History. December, 1903.

P. H. MELL, M. E., Ph. D., 165 East 10th St., Atlanta, Ga. December, 1888.

WALTER C. MENDENHALL, B. S., Washington, D. C.; Geologist, U. S. Geological Survey. June, 1902.

JOHN C. MERRIAM, Ph. D., Berkeley, Cal.; Instructor in Paleontology in University of California. August, 1895.

*FREDERICK J. H. MERRILL, Ph. D., Nogales, Arizona.

GEORGE P. MERRILL, Ph. D., Washington, D. C.; Curator of Department of Lithology and Physical Geology in U. S. National Museum. December, 1888.

ARTHUR M. MILLER, A. M., Lexington, Ky.; Professor of Geology, State University of Kentucky. December, 1897.

BENJAMIN L. MILLER, Ph. D., South Bethlehem, Pa.; Professor of Geology, Lehigh University. December, 1904.

WILLET G. MILLER, M. A., Toronto, Canada; Provincial Geologist of Ontario. December, 1902.

HENRY MONTGOMERY, Ph. D., Toronto, Canada; Curator of Museum, University of Toronto. December, 1904.

*FRANK L. NASON, A. B., West Haven, Conn.

DAVID HALE NEWLAND, B. A., Albany, N. Y.; Assistant State Geologist. December, 1906.

JOHN F. NEWSOM, Ph. D., Stanford University, Cal.; Associate Professor of Mining in Leland Stanford, Jr., University. December, 1899.

WILLIAM H. NILES, Ph. D., M. A., Boston, Mass.; Professor Emeritus of Geology, Massachusetts Institute of Technology; Professor of Geology, Wellesley College. August, 1891.

WILLIAM H. NORTON, M. A., Mount Vernon, Iowa; Professor of Geology in Cornell College. December, 1895.

CHARLES J. NORWOOD, Lexington, Ky.; Professor of Mining, State University of Kentucky. August, 1894.

IDA HELEN OGILVIE, A. B., Ph. D., New York City; Tutor in Geology, Barnard College, Columbia University. December, 1906.

CLEOPHAS C. O'HARRA, Ph. D., Rapid City, S. Dak.; Professor of Mineralogy and Geology, South Dakota School of Mines. December, 1904.

EZEQUIEL ORDONEZ, 2 a General Prine, Mexico, D. F., Mex. August, 1896.

*AMOS O. OSBORN, Waterville, Oneida county, N. Y.

HENRY F. OSBORN, Sc. D., New York City; President of the American Museum of Natural History. August, 1894.

CHARLES PALACHE, B. S., Cambridge, Mass.; Instructor in Mineralogy, Harvard University. August, 1897.

WILLIAM A. PARKS, B. A., Ph. D., Toronto, Canada; Associate Professor of Geology, University of Toronto. December, 1906.

*HORACE B. PATTON, Ph. D., Golden, Colo.; Professor of Geology and Mineralogy in Colorado School of Mines.

FREDERICK B. PECK, Ph. D., Easton, Pa.; Professor of Geology and Mineralogy, Lafayette College. August, 1901.

DAVID PEARCE PENHALLOW, B. S., M. S., Sc. D., Montreal, Canada; Professor of Botany in McGill University. December, 1907.

RICHARD A. F. PENROSE, JR., Ph. D., 460 Bullitt Building, Philadelphia, Pa. May, 1889.

GEORGE H. PERKINS, Ph. D., Burlington, Vt.; State Geologist; Professor of Geology, University of Vermont. June, 1902.

JOSEPH H. PERRY, 276 Highland St., Worcester, Mass. December, 1888.

LOUIS V. PIRSSON, Ph. D., New Haven, Conn.; Professor of Physical Geology Sheffield Scientific School of Yale University. August, 1894.

JOSEPH HYDE PRATT, Ph. D., Chapel Hill, N. C.; Mineralogist, North Carolina Geological Survey. December, 1898.

*CHARLES S. PROSSER, M. S., Columbus, Ohio; Professor of Geology in Ohio State University.

*RAPHAEL PUMPELLY, Newport, R. I.

ALBERT HOMER PURDUE, B. A., Fayetteville, Ark.; Professor of Geology, University of Arkansas. December, 1904.

FREDERICK LESLIE RANSOME, Ph. D., Washington, D. C.; Geologist, U. S. Geological Survey. August, 1895.

PERCY EDWARD RAYMOND, B. A., Ph. D., Pittsburgh, Pa.; Assistant Curator of Invertebrate Fossils in the Carnegie Museum. December, 1907.

HARRY FIELDING REID, Ph. D., Baltimore, Md.; Professor of Geological Physics, Johns Hopkins University. December, 1892.

WILLIAM NORTH RICE, Ph. D., LL. D., Middletown, Conn.; Professor of Geology in Wesleyan University. August, 1890.

CHARLES H. RICHARDSON, Ph. D., Syracuse, N. Y.; Assistant Professor of Geology and Mineralogy, Syracuse University. December, 1899.

GEORGE BURR RICHARDSON, S. B., S. M., Ph. D., Washington, D. C.; U. S. Geological Survey. December, 1908.

HEINRICH RIES, Ph. D., Ithaca, N. Y.; Professor of Economic Geology in Cornell University. December, 1893.

RUDOLPH RUEDEMANN, Ph. D., Albany, N. Y.; Assistant State Paleontologist. December, 1905.

ORESTES H. ST. JOHN, 1141 Twelfth St., San Diego, Cal. May, 1889.

*ROLLIN D. SALISBURY, A. M., Chicago, Ill.; Professor of General and Geographic Geology in University of Chicago.

FREDERICK W. SARDESON, Ph. D., Minneapolis, Minn.; Assistant Professor of Geology, University of Minnesota. December, 1892.

THOMAS EDMUND SAVAGE, A. B., B. S., M. S., Urbana, Ill.; Department of Geology, University of Illinois. December, 1907.

FRANK C. SCHRADER, M. S., A. M., Washington, D. C.; U. S. Geological Survey. August, 1901.

CHARLES SCHUCHERT, New Haven, Conn.; Professor of Paleontology, Yale University. August, 1895.

WILLIAM B. SCOTT, Ph. D., 56 Bayard Ave., Princeton, N. J.; Blair Professor of Geology in Princeton University. August, 1892.

ARTHUR EDMUND SEAMAN, B. S., Houghton, Mich.; Professor of Mineralogy and Geology, Michigan College of Mines. December, 1904.

HENRY M. SEELY, M. D., Middlebury, Vt.; Professor of Geology in Middlebury College. May, 1899.

ELIAS H. SELLARDS, Ph. D., Tallahassee, Fla.; State Geologist. December, 1905.

JOAQUIM CANDIDO DA COSTA SEÑA, Ouro Preto, Brazil; Director of the State School of Mines and Professor of Mineralogy and Geology. December, 1908.

GEORGE BURBANK SHATTUCK, Ph. D., Poughkeepsie, N. Y.; Professor of Geology in Vassar College. August, 1899.

SOLON SHEDD, A. B., Pullman, Wash.; Professor of Geology and Mineralogy, Washington Agricultural College. December, 1904.

EDWARD M. SHEPARD, Sc. D., Springfield, Mo.; Professor of Geology, Drury College. August, 1901.

WILL H. SHERZER, M. S., Ypsilanti, Mich.; Professor in State Normal School, December, 1890.

BOHUMIL SHIMEK, C. E., M. S., Iowa City, Iowa; Professor of Physiological Botany, University of Iowa. December, 1904.

*FREDERICK W. SIMONDS, Ph. D., Austin, Texas; Professor of Geology in University of Texas.

WILLIAM JOHN SINCLAIR, B. S., Ph. D., Princeton, N. J.; Instructor in Princeton University. December, 1906.

EARLE SLOAN, Charleston, S. C.; State Geologist of South Carolina. December, 1908.

*EUGENE A. SMITH, Ph. D., University, Tuscaloosa county, Ala.; State Geologist and Professor of Chemistry and Geology in University of Alabama.

FRANK CLEMES SMITH, E. M., Richland Center, Wis. December, 1898.

GEORGE OTIS SMITH, Ph. D., Washington, D. C.; Director, U. S. Geological Survey. August, 1897.

WILLIAM S. T. SMITH, Ph. D., 839 Lake St., Reno, Nev.; Associate Professor of Geology and Mineralogy, University of Nevada. June, 1902.

*JOHN C. SMOCK, Ph. D., Trenton, N. J.

CHARLES H. SMYTH, JR., Ph. D., Princeton, N. J.; Professor of Geology in Princeton University. August, 1892.

HENRY L. SMYTH, A. B., Cambridge, Mass.; Professor of Mining and Metallurgy in Harvard University. August, 1894.

ARTHUR COE SPENCER, B. S., Ph. D., Washington, D. C.; Assistant Geologist, U. S. Geological Survey. December, 1896.

*J. W. SPENCER, Ph. D., 2019 Hillyer Place, Washington, D. C.

JOSIAH E. SPURR, A. B., A. M., 165 Broadway, New York City. December, 1894.

JOSEPH STANLEY-BROWN, Cold Spring Harbor, Long Island, N. Y. August, 1892.

TIMOTHY WILLIAM STANTON, B. S., U. S. National Museum, Washington, D. C.; Assistant Paleontologist, U. S. Geological Survey. August, 1891.

*JOHN J. STEVENSON, Ph. D., LL. D., 568 West End Ave., New York City.

GEORGE WILLIS STOSE, B. S., Washington, D. C.; U. S. Geological Survey. December, 1908.

WILLIAM J. SUTTON, B. S., E. M., Victoria, B. C.; Geologist to E. and N. Railway Co. August, 1901.

CHARLES KEPHART SWARTZ, A. B., Ph. D., Baltimore, Md.; Associate Professor of Geology in Johns Hopkins University. December, 1908.

JOSEPH A. TAFF, B. S., Palo Alto, Cal.; Assistant Geologist, U. S. Geological Survey. August, 1895.

JAMES E. TALMAGE, Ph. D., Salt Lake City, Utah; Professor of Geology in University of Utah. December, 1897.

RALPH S. TARR, Ithaca, N. Y.; Professor of Dynamic Geology and Physical Geography in Cornell University. August, 1890.

FRANK B. TAYLOR, Fort Wayne, Ind. December, 1895.

WILLIAM G. TIGHT, M. S., Albuquerque, N. Mex. August, 1897.

*JAMES E. TODD, A. M., 113 Park St., Lawrence, Kas.; Assistant Geologist, U. S. Geological Survey.

*HENRY W. TURNER, B. S., Room 709, Mills Building, San Francisco, Cal.

JOSEPH B. TYRRELL, M. A., B. Sc., Room 534, Confederation Life Bldg., Toronto, Canada. May, 1889.

JOHAN A. UDDEN, A. M., Rock Island, Ill.; Professor of Geology and Natural History in Augustana College. August, 1897.

EDWARD O. ULRICH, D. Sc., Washington, D. C.; Assistant Geologist, U. S. Geological Survey. December, 1903.

*WARREN UPHAM, A. M., Saint Paul, Minn.; Librarian Minnesota Historical Society.

*CHARLES R. VAN HISE, M. S., Ph. D., Madison, Wis.; President University of Wisconsin; Geologist, U. S. Geological Survey.

FRANK ROBERTSON VAN HORN, Ph. D., Cleveland, Ohio; Professor of Geology and Mineralogy, Case School of Applied Science. December, 1898.

GILBERT VAN INGEN, Princeton, N. J.; Curator of Invertebrate Paleontology and Assistant in Geology, Princeton University. December, 1904.

THOMAS WAYLAND VAUGHAN, B. S., A. M., Washington, D. C.; Assistant Geologist, U. S. Geological Survey. August, 1896.

ARTHUR CLIFFORD VEACH, Washington, D. C.; Geologist, U. S. Geological Survey. December, 1906.

*ANTHONY W. VOGDES, 2425 First St., San Diego, Cal.; Brigadier General, U. S. A. (Retired).

*M. EDWARD WADSWORTH, Ph. D., Pittsburgh, Pa.; Dean of the School of Mines in the University of Pittsburgh.

*CHARLES D. WALCOTT, LL. D., Washington, D. C.; Secretary Smithsonian Institution.

THOMAS L. WALKER, Ph. D., Toronto, Canada; Professor of Mineralogy and Petrography, University of Toronto. December, 1903.

CHARLES H. WARREN, Ph. D., Boston, Mass.; Instructor in Geology, Massachusetts Institute of Technology. December, 1901.

HENRY STEPHENS WASHINGTON, Ph. D., Locust, Monmouth Co., N. J.; August, 1896.

THOMAS L. WATSON, Ph. D., Charlottesville, Va.; Professor of Geology in University of Virginia. June, 1900.

WALTER H. WEED, E. M., Norwalk, Conn. May, 1889.

FRED. BOUGHTON WEEKS, Washington, D. C.; Assistant Geologist, U. S. Geological Survey. December, 1903.

SAMUEL WEIDMAN, Ph. D., Madison, Wis.; Geologist, Wisconsin Geological and Natural History Survey. December, 1903.

STUART WELLER, B. S., Chicago, Ill.; Associate Professor of Paleontologic Geology, University of Chicago. June, 1900.

LEWIS G. WESTGATE, Ph. D., Delaware, Ohio; Professor of Geology, Ohio Wesleyan University.

THOMAS C. WESTON, care of A. Patton, Levis, Quebec, Canada. August, 1893.

DAVID WHITE, B. S., U. S. National Museum, Washington, D. C.; Geologist, U. S. Geological Survey. May, 1889.

*ISRAEL C. WHITE, Ph. D., Morgantown, W. Va.

*ROBERT P. WHITFIELD, A. M., New York City; Curator Emeritus of Geology and Invertebrate Paleontology, American Museum of Natural History.

FRANK A. WILDER, Ph. D., North Holston, Smyth Co., Va. December, 1905.

*EDWARD H. WILLIAMS, JR., A. C., E. M., Andover, Mass.

*HENRY S. WILLIAMS, Ph. D., Ithaca, N. Y.; Professor of Geology and Head of Geological Department, Cornell University.

IRA A. WILLIAMS, M. Sc., Ames, Iowa; Teacher Iowa State College. December, 1905.

BAILEY WILLIS, Washington, D. C.; U. S. Geological Survey. December, 1889.

SAMUEL W. WILLISTON, Ph. D., M. D., Chicago, Ill.; Professor of Paleontology, University of Chicago. December, 1889.

ARTHUR B. WILLMOTT, M. A., 24 Adelaide St., W., Toronto, Canada. December, 1899.

ALFRED W. G. WILSON, Ph. D., Mines Branch, Department of Mines, Ottawa, Canada. June, 1902.

ALEXANDER N. WINCHELL, Doct. U. Paris, Madison, Wis.; Professor of Geology and Mineralogy, University of Wisconsin. August, 1901.

*HORACE VAUGHN WINCHELL, 505 Palace Building, Minneapolis, Minn.

*NEWTON H. WINCHELL, A. M., 501 East River Road, Minneapolis, Minn.

*ARTHUR WINSLOW, B. S., 131 State St., Boston, Mass.

JOHN E. WOLFF, Ph. D., Cambridge, Mass.; Professor of Petrography and Mineralogy in Harvard University and Curator of the Mineralogical Museum. December, 1889.

JOSEPH E. WOODMAN, S. D., New York City; Professor of Geology in New York University. December, 1905.

ROBERT S. WOODWARD, C. E., Washington, D. C.; President of the Carnegie Institution of Washington. May, 1889.

JAY B. WOODWORTH, B. S., 24 Langdon St., Cambridge, Mass.; Assistant Professor of Geology, Harvard University. December, 1895.

FREDERIC E. WRIGHT, Ph. D., Washington, D. C.; Geophysical Laboratory, Carnegie Institution. December, 1903.

*G. FREDERICK WRIGHT, D. D., Oberlin, Ohio; Professor in Oberlin Theological Seminary.

GEORGE A. YOUNG, Ph. D., Ottawa, Canada; Geologist, Geological Survey of Canada. December, 1905.

FELLOWS-ELECT

WILLIAM CLINTON ALDEN, A. B., A. M., Ph. D., Washington, D. C. Assistant Geologist, U. S. Geological Survey. December, 1909.

WALLACE WALTER ATWOOD, B. S., Ph. D., Chicago, Illinois. Instructor at University of Chicago and Assistant Geologist, U. S. Geological Survey. December, 1909.

EDSON SUNDERLAND BASTIN, A. B., A. M., Washington, D. C. Assistant Geologist, U. S. Geological Survey. December, 1909.

EDWARD WILBER BERRY, Baltimore, Maryland. Instructor in Paleontology, Johns Hopkins University. December, 1909.

WILLIS STANLEY BLATCHLEY, A. B., A. M., State House, Indianapolis, Indiana. State Geologist of Indiana. December, 1909.

HENRY ANDREW BUEHLER, B. S., Rolla, Missouri. State Geologist of Missouri. December, 1909.

FRED HARVEY HALL CALHOUN, B. S., Ph. D., Clemson College, South Carolina. Professor of Geology and Mineralogy, Clemson College, and Assistant Geologist, U. S. Geological Survey. December, 1909.

ARTHUR LOUIS DAY, B. A., Ph. D., Washington, D. C. Director, Geophysical Laboratory, Carnegie Institution of Washington. December, 1909.

FRANK WILBRIDGE DE WOLF, S. B., Urbana, Illinois. Assistant State Geologist of Illinois and Assistant Geologist, U. S. Geological Survey. December, 1909.

JAMES WALTER GOLDTHWAIT, A. B., A. M., Ph. D., Hanover, New Hampshire. Assistant Professor of Geology in Dartmouth College and head of department. December, 1909.

BAIRD HALBERSTADT, Pottsville, Pennsylvania. Engineer and Geologist. December, 1909.

OSCAR H. HERSHEY, Kellogg, Idaho. December, 1909.

FREDERICK BREWSTER LOOMIS, B. A., Ph. D., Amherst, Massachusetts. Professor of Comparative Anatomy in Amherst College. December, 1909.

RICHARD SWANN LULL, B. S., M. S., Ph. D., New Haven, Connecticut. Assistant Professor of Vertebrate Paleontology, Yale University. December, 1909.

GEORGE ROGERS MANSFIELD, B. S., A. M., Ph. D., Evanston, Illinois. Assistant Professor of Geology, Northwestern University. December, 1909.

LAWRENCE MARTIN, A. B., A. M., Madison, Wisconsin. Instructor in Geology, University of Wisconsin. December, 1909.

SAMUEL WASHINGTON MCCALLIE, Ph. B., Atlanta, Georgia. State Geologist of Georgia. December, 1909.

WILLIAM JOHN MILLER, S. B., Ph. D., Clinton, New York. Professor of Geology and Mineralogy in Hamilton College. December, 1909.

MALCOLM JOHN MUNN, Washington, D. C. Assistant Geologist, U. S. Geological Survey. December, 1909.

EDWARD ORTON, JR., E. M., Columbus, Ohio. Assistant Geologist, Geological Survey of Ohio. December, 1909.

PHILIP S. SMITH, A. B., A. M., Ph. D., Washington, D. C. Assistant Geologist, U. S. Geological Survey. December, 1909.

WARREN DU PRÉ SMITH, B. S., A. M., Ph. D., Manila, Philippine Islands. Chief of the Mining Bureau. December, 1909.

CYRUS FISHER TOLMAN, JR., B. S., Tucson, Arizona. Professor of Geology and Mining in the University of Arizona. December, 1909.

CHARLES WILL WRIGHT, B. S., M. E., Washington, D. C. Assistant Geologist, U. S. Geological Survey. December, 1909.

FELLOWS DECEASED

*Indicates Original Fellow (see article III of Constitution)

*Charles A. Ashburner, M. S., C. E. Died December 24, 1889.
Charles E. Beecher, Ph. D. Died February 14, 1904.
Amos Bowman. Died June 18, 1894.
*J. H. Chapin, Ph. D. Died March 14, 1892.
*Edward W. Claypole, D. Sc. Died August 17, 1901.
George H. Cook, Ph. D., LL. D. Died September 22, 1889.
*Edward D. Cope, Ph. D. Died April 12, 1897.
Antonio Del Castillo. Died October 28, 1895.
*James D. Dana, LL. D. Died April 14, 1895.
George M. Dawson, D. Sc. Died March 2, 1901.
Sir J. William Dawson, LL. D. Died November 19, 1899.
*William B. Dwight, Ph. B. Died August 29, 1906.
*George H. Eldridge, A. B. Died June 29, 1905.
*Albert E. Foote. Died October 10, 1895.
*Persifor Frazer. Died April 7, 1909.
*Homer T. Fuller. Died August 14, 1908.
N. J. Giroux, C. E. Died November 30, 1890.
*James Hall, LL. D. Died August 7, 1898.
John B. Hatcher, Ph. B. Died July 3, 1904.
*Robert Hay. Died December 14, 1895.
*Angelo Heilprin. Died July 17, 1907.
David Honeyman, D. C. L. Died October 17, 1889.
Thomas Sterry Hunt, D. Sc., LL. D. Died February 12, 1892.
*Alpheus Hyatt, B. S. Died January 15, 1902.
*Joseph F. James, M. S. Died March 29, 1897.
Wilbur C. Knight, B. S., A. M. Died July 28, 1903.
Ralph D. Lacoe. Died February 5, 1901.
Daniel W. Langton. Died June 21, 1909.
*Joseph Le Conte, M. D., LL. D. Died July 6, 1901.
*J. Peter Lesley, LL. D. Died June 2, 1903.
Henry McCalley, A. M., C. E. Died November 20, 1904.
Oliver Marcy, LL. D. Died March 19, 1899.
Othniel C. Marsh, Ph. D., LL. D. Died March 18, 1899.
James E. Mills, B. S. Died July 25, 1901.
*Henry B. Nason, M. D., Ph. D., LL. D. Died January 17, 1895.
*Peter Neff, M. A. Died May 11, 1903.
*John S. Newberry, M. D., LL. D. Died December 7, 1892.
*Edward Orton, Ph. D., LL. D. Died October 16, 1899.
*Richard Owen, LL. D. Died March 24, 1890.
Samuel L. Penfield. Died August 14, 1906.
*Franklin Platt. Died July 24, 1900.
William H. Pettee, A. M. Died May 26, 1904.
*John Wesley Powell, LL. D. Died September 23, 1902.
*Israel C. Russell, LL. D. Died May 1, 1906.
*James M. Safford, M. D., LL. D. Died July 3, 1907.

*Charles Schaeffer, M. D. Died November 23, 1903.
*Nathaniel S. Shaler, LL. D. Died April 10, 1906.
Charles Wachsmuth. Died February 7, 1896.
Theodore G. White, Ph. D. Died July 7, 1901.
*George H. Williams, Ph. D. Died July 12, 1894.
*J. Francis Williams, Ph. D. Died September 9, 1891.
*Alexander Winchell, LL. D. Died February 19, 1891.
Albert A. Wright, Ph. D. Died April 2, 1905.
William S. Yeates. Died February 19, 1908.

Summary

Original Fellows	58
Elected Fellows	252
Membership	310
Deceased Fellows	54

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
VOL. 21, PP. 69-86 MARCH 31, 1910

PROCEEDINGS OF THE PRELIMINARY MEETING OF THE PALEONTOLOGICAL SOCIETY, HELD AT BALTIMORE, MARYLAND, DECEMBER 30, 1908, AND ALSO PROCEEDINGS OF THE FIRST ANNUAL MEETING HELD AT CAMBRIDGE, MASSACHUSETTS, DECEMBER 29, 1909.

HERDMAN F. CLELAND, *Secretary*

CONTENTS

The Paleontological Society: Page
Preliminary meeting for the organization of a Paleontological Society. 69
Report of the Organization Committee of the Paleontological Society. 71
First annual meeting of the Paleontological Society:
Report of the Secretary 72
Election of officers 72
Election of members 73
Program 73
Constitution and By-Laws of the Paleontological Society 77
Officers and members of the Paleontological Society 83

PRELIMINARY MEETING FOR THE ORGANIZATION OF A PALEONTOLOGICAL SOCIETY

The meeting for the purpose of organizing a paleontological society was called to order by Prof. Charles Schuchert, in the Geological Laboratory of Johns Hopkins University, Baltimore, at 9.10 a. m., December 30, 1908. Mr. T. W. Stanton was appointed Secretary *pro tempore*.

The following persons were present and by their signatures signified their intention to take part in organizing the Paleontological Society of America: H. M. Ami, Ralph Arnold, R. M. Bagg, Jr., R. S. Bassler, J. W. Beede, E. W. Berry, E. C. Case, William Bullock Clark, John M. Clarke, Harold J. Cook, Edgar R. Cumings, August F. Foerste, J. W. Gidley, Charles W. Gilmore, A. W. Grabau, Edwin Kirk, F. H. Knowlton, E. B. Loomis, R. S. Lull, W. D. Matthew, Henry Fairfield Osborn, Charles S. Prosser, P. S. Raymond, E. S. Riggs, T. E. Savage, Charles Schuchert, H. W. Shimer, T. W. Stanton, E. O. Ulrich, Charles D. Walcott, Stuart Weller, David White, Henry S. Williams, S. W. Williston.

Professor Schuchert outlined the history of the movement for the organization of a paleontological society, and presented a preliminary plan drawn up by the temporary committee, of which he had acted as chairman. At the New Haven meeting of the Society of American Vertebrate Paleontologists, in 1907, there was a general discussion in which several members favored the formation of a society of broader scope, in which workers in all branches of paleontologic research could be united. As a result of this discussion and of a suggestion that grew out of it, Professor Schuchert invited Messrs. John M. Clarke, F. B. Loomis, William J. Sinclair, T. W. Stanton, E. O. Ulrich, C. D. Walcott, David White, and S. W. Williston to cooperate with him as a committee to consider ways and means of organizing a paleontological society. This committee sent out a circular to all the paleontologists of the country inviting them to vote on the general question of organization and on several details, such as whether the society should be independent or a section of the Geological Society of America, what kind of a publication is practicable, etcetera. The committee also issued the call for this meeting, and outlined a constitution modeled after that of the Geological Society. The principal features of the proposed constitution were presented to the meeting by the chairman.

On motion of Dr. C. D. Walcott, an executive committee on organization, with full power to act for the society, was formed, consisting of Charles Schuchert, F. B. Loomis, S. W. Williston, David White, H. F. Osborn, and T. W. Stanton.

Prof. William Bullock Clark, as a member of the Council of the Geological Society of America, read a resolution adopted by that Council, expressing sympathy with the movement to organize the paleontologists and suggesting a joint committee to adjust details of affiliation.

On motion, the Executive Committee of the Paleontological Society was empowered to act for the paleontologists with a committee to be appointed by the Council of the Geological Society of America to adjust relations with that Society.

The Executive Committee was authorized to elect the officers of the Society for 1909.

At 10 a. m. the meeting adjourned.

(Signed) T. W. STANTON,
Secretary pro tem.

Report of the Organization Committee of the Paleontological Society

Pursuant to the call of the chairman, the Executive Committee of the Paleontological Society met with a special committee of the Geological Society of America in the American Museum of Natural History, New York City, at 10 a. m., February 13, 1909, for the purpose of adjusting the relations between the two societies. There were present Messrs. F. B. Loomis, David White, and T. W. Stanton, representing the Paleontological Society of America, and Messrs. W. B. Clark, J. M. Clarke, H. E. Gregory, and E. O. Hovey, representing the Geological Society of America. W. B. Clark acted as chairman of the conference.

From the preliminary discussion it was evident that the majority of those interested in the organization of a paleontological society were in favor of making it a section of the Geological Society of America, as expressed in a previous vote, and that the Geological Society was willing to recognize such a section and to assist it by increasing facilities for publishing paleontologic papers and in other ways, so far as its financial condition would allow.

A provisional draft of a "Constitution and By-Laws of the Paleontological Society of America," based on those of the Geological Society and prepared by Professor Schuchert, was read by paragraphs and informally discussed, and amended so as to make it consistent with the form of organization agreed upon, namely, a section of the Geological Society of America.

On the suggestion of Dr. J. M. Clarke, it was decided to adopt "The Paleontological Society" as the name of the organization, the qualifying phrase "of America" being unnecessary, since there is no other paleontological society.

After the adjournment of the conference, the Executive Committee reassembled and ratified the Constitution and By-Laws as amended in the joint session.[1] Under the authority granted at the preliminary meeting in Baltimore on December 30, 1908, the committee proceeded to elect officers for the remainder of this year as follows:

President, J. M. Clarke.
First Vice-President, J. C. Merriam.
Second Vice-President, T. W. Stanton.
Third Vice-President, David White.
Treasurer, W. D. Matthew.
Secretary, H. F. Cleland.
Editor, C. R. Eastman.

[1] The Constitution and By-Laws of the Paleontological Society are published as pages 77-82 of this volume.

It is understood that this board will hold office only until the close of the first annual meeting, and that in accordance with the provisions of the Constitution and By-Laws they must prepare and send out a list of nominations for their successors within thirty days.

It was also agreed that the selection of the First, Second, and Third Vice-Presidents, respectively, from the Vertebrate, Invertebrate, and Botanical Sections is not a permanent arrangement, but that the order of precedence should be changed from time to time.

Adjourned.

T. W. STANTON,
Secretary.

FIRST ANNUAL MEETING OF THE PALEONTOLOGICAL SOCIETY

The first annual meeting of the Paleontological Society was called to order by President John M. Clarke at 10 o'clock a. m., Wednesday, December 29, 1909, in the Nash Lecture Hall of the Botanical Museum, Harvard University, Cambridge, Massachusetts.

REPORT OF THE SECRETARY

To the Members of The Paleontological Society:

During the year notices of the organization of The Paleontological Society, with a statement of the qualifications for membership, were sent to the paleontologists of Canada, Mexico, Brazil, and the United States. To these a prompt and encouraging reply was received from the majority of the paleontologists to whom the notices were sent.

As a result of these circular letters and of the correspondence carried on by members of the Council, the membership of the Society at present is as given in the accompanying list (pages 83-86).

The following resolutions were adopted by the Council:

Resolved, That the Council of the Paleontological Society invites the entire membership of the Society of American Vertebrate Paleontologists to enroll as members of the Paleontological Society; and further

Resolved, That the members of the Vertebrate Paleontological Society shall immediately on such adhesion and qualification be enrolled in the membership of the Paleontological Society without further formality.

Election of officers.—At the meeting of the Council held at the rooms of the President, in Copley Square Hotel, December 28, 1909, the ballots were opened. Forty-two votes were received, all of which were cast for the officers who were nominated by the Council.

The officers and Council for the year 1910 are as follows:

President:

CHARLES SCHUCHERT, New Haven, Conn.

First Vice-President:

E. O. ULRICH, Washington, D. C.

Second Vice-President:

S. W. WILLISTON, Chicago, Ill.

Third Vice-President:

F. H. KNOWLTON, Washington, D. C.

Secretary:

HERDMAN F. CLELAND, Williamstown, Mass.[2]

Treasurer:

W. D. MATTHEW, New York City.

Editor:

CHARLES R. EASTMAN, Cambridge, Mass.

Election of members.—All persons proposed for membership were elected without opposition. The list will be found on page 86.

Program.—After the presidential address by Dr. John M. Clarke, a "Conference on the Aspects of Paleontology" was held, at which papers on assigned topics were read by members of the Society by invitation of the Council, as follows:

ADEQUACY OF THE PALEONTOLOGIC RECORD

BY R. S. BASSLER

INTERDEPENDENCE OF STRATIGRAPHY AND PALEONTOLOGY

BY W. J. SINCLAIR AND E. O. ULRICH

BIOLOGIC PRINCIPLES OF PALEOGEOGRAPHY

BY CHARLES SCHUCHERT

PALEONTOLOGIC EVIDENCES OF CLIMATE

BY T. W. STANTON AND DAVID WHITE

MIGRATION

BY HENRY S. WILLIAMS AND ARTHUR HOLLICK

[2] Herdman F. Cleland resigned, and R. S. Bassler, of Washington, D. C., was elected by the Council to fill the vacancy.

PALEONTOLOGIC EVIDENCES OF ADAPTIVE RADIATION

BY H. FAIRFIELD OSBORN

ANATOMY AND PHYSIOLOGY IN EXTINCT ORGANISMS

BY CHARLES R. EASTMAN AND RUDOLPH RUEDEMANN

CONTRIBUTIONS TO MORPHOLOGY FROM PALEONTOLOGY

BY WILLIAM BULLOCK CLARK

EMBRYOLOGY AND PALEONTOLOGY

BY RICHARD S. LULL AND WILLIAM H. DALL

ONTOGENY AND PALEONTOLOGY

BY F. B. LOOMIS AND AMADEUS W. GRABAU

PHYLOGENY AND PALEONTOLOGY

BY ROBERT T. JACKSON AND D. P. PENHALLOW

PALEONTOLOGIC EVIDENCES OF RECAPITULATION

BY E. R. CUMMINGS AND L. HUSSAKOF

ISOLATION IN PALEONTOLOGY

BY JOHN M. CLARKE

CONTINUITY OF DEVELOPMENT FROM THE PALEONTOLOGIC STANDPOINT

BY T. WAYLAND VAUGHAN

PALEONTOLOGY OF MAN

BY S. W. WILLISTON

Then were read general papers, as follows:

VARANOSAURUS SPECIES, A PERMIAN PELYCOSAUR

BY S. W. WILLISTON

Discussed by H. F. Osborn, W. J. Sinclair, and W. J. Holland.

THE STRUCTURE OF THE SAUROPOD DINOSAURS

BY W. J. HOLLAND

Discussed by S. W. Williston.

PHYLOGENY OF THE FELIDÆ

BY W. D. MATTHEW

(By title)

OSTEOLOGY AND RELATIONSHIPS OF PARAMYS AND THE AFFINITIES OF THE ISCHYROMYIDÆ

BY W. D. MATTHEW

(By title)

PHYLOGENETIC POSITION OF THE GENUS STEGOMYLUS

BY F. B. LOOMIS

THE ARMOR OF STEGOSAURUS

BY R. S. LULL

Discussed by H. F. Osborn and W. J. Holland.

RESTORATION OF PALEOLITHIC MAN

BY R. S. LULL

NEW GENUS OF PERMIAN REPTILE

BY S. W. WILLISTON

PRINCIPAL CHARACTER OF THE CHELYDROSAURIA, A SUB-ORDER OF TEMNOSPONDYTE AMPHIBIANS FROM THE TEXAS PERMIAN

BY S. W. WILLISTON

SKULL OF TYRANNOSAURUS

BY H. F. OSBORN

ANDERSON'S METHODS OF PHOTOGRAPHY IN VERTEBRATE PALEONTOLOGY

BY H. F. OSBORN

CORRELATION OF THE PLEISTOCENE OF EUROPE AND AMERICA

BY H. F. OSBORN

LARAMIE FLORA OF SOUTHWESTERN WYOMING

BY F. H. KNOWLTON

(By title)

PERMIAN FLORAS IN THE WESTERN "RED BEDS"[3]

BY DAVID WHITE

Discussed by C. Schuchert, J. W. Beede, J. M. Clarke, and E. O. Ulrich.

ORDOVICIC-SILURIC SECTION OF THE MINGAN AND ANTICOSTI ISLANDS

BY CHARLES SCHUCHERT AND W. H. TWENHOFEL

Discussed by E. O. Ulrich and A. W. Grabau.

[3] From the Geological Society's program.

PERSISTENCE OF FLUCTUATING VARIATIONS AS ILLUSTRATED BY THE GENUS RHIPIDOMELLA

BY HENRY S. WILLIAMS

MIGRATIONS AND THE SHIFTING OF DEVONIAN FAUNAS

BY HENRY S. WILLIAMS

(By title)

INTRACOLONIAL ACCELERATION AND RETARDATION AND ITS BEARING ON SPECIES

BY AMADEUS W. GRABAU

FAUNA OF THE GIRARDEAU LIMESTONE AND OF THE EDGEWOOD FORMATION

BY T. E. SAVAGE

PHYLOGENY OF CERTAIN CERITHIIDÆ

BY ELVIRA WOOD

MODE OF LIFE OF THE EURYPTERIDA

BY JOHN M. CLARKE AND RUDOLPH RUEDEMANN

PLIOCENE AND PLEISTOCENE FORAMINIFERA FROM CALIFORNIA

BY RUFUS M. BAGG, JR.

(By title)

INTERNAL CHARACTERS OF SOME MISSISSIPPIAN RHYNCHONELLOID SHELLS

BY STUART WELLER

(By title)

NEW CYSTID FROM THE CLINTON FORMATION OF ONTARIO

BY W. A. PARKS

SOME NEW FOSSILS FROM THE CAMBRIAN OF SOUTH ATTLEBORO, MASS.

BY W. B. HALL[4]

NOTES ON THE UPPER CARBONIFEROUS IN SOUTHEAST NEW MEXICO AND WEST TEXAS

BY G. B. RICHARDSON

CORRELATION OF THE GUADALUPIAN AND KANSAS SECTIONS

BY J. W. BEEDE

HERDMAN F. CLELAND,
Secretary.

[4] Introduced by R. S. Lull.

CONSTITUTION AND BY-LAWS OF THE PALEONTOLOGICAL SOCIETY

CONSTITUTION

ARTICLE I

NAME

This Society shall be known as THE PALEONTOLOGICAL SOCIETY. It is affiliated with and forms a section of the Geological Society of America. The two societies shall, as a rule, meet together.

ARTICLE II

OBJECT

The object of this Society is the promotion of the Science of Paleontology.

ARTICLE III

MEMBERSHIP

The Society shall be composed of Fellows, Members, Correspondents, and Patrons.

1. Fellows shall be persons who have published results of paleontological research, and who upon nomination by the Council have been duly elected to fellowship by the Geological Society of America.

2. Members shall be persons not Fellows who are engaged or interested in paleontological work.

3. Correspondents shall be persons distinguished for their attainments in Paleontology and not resident in North America.

4. Patrons shall be persons who have bestowed important favors upon the Society. Election to patronship carries with it the rights and privileges of Members.

5. Fellows, Members, and Patrons are entitled to vote, but only Fellows are eligible to office in this Society.

ARTICLE IV

OFFICERS

1. The Officers of the Society are a President, three Vice-Presidents, a Secretary, a Treasurer, and an Editor.

These officers constitute an Executive Committee to be called the Council.

2. The President shall discharge the usual duties of a presiding officer at all meetings of the Society and of the Council. He shall take cognizance of the acts of the Society and of its officers, and cause the provisions of the Constitution and By-Laws to be faithfully carried into effect. The President shall also represent THE PALEONTOLOGICAL SOCIETY in the Council of the Geological Society of America.

3. The Vice-Presidents, in the order of their precedence, shall assume the duties of President in case of the absence or disability of the latter.

The three Vice-Presidents represent respectively the three chief branches of paleontology, and it shall be the duty of each to look after the interests and preside at the meetings of the section which he represents.

4. The Secretary shall keep the records of the proceedings of the Society, and a complete list of the Fellows, Members, Correspondents, and Patrons, with the dates of their election to and separation from the Society. He shall also be the Secretary of the Council.

The Secretary shall cooperate with the President in attention to the ordinary affairs of the Society. He shall attend to the preparation, printing, and mailing of circulars, blanks, and notifications of elections and meetings. He shall superintend other printing ordered by the Society or by the President, and shall have charge of its distribution, under the direction of the Council.

The Secretary, unless other provision be made, shall act as Librarian, and as Custodian of the property of the Society, except as provided for in Article IV, section 6.

5. The Treasurer shall have the custody of all funds of the Society except the fees of Fellows. He shall keep account of receipts and disbursements in detail, and this shall be audited as hereinafter provided.

6. The Editor shall supervise all matters connected with the publication of the transactions of the Society under the direction of the Council. He shall also be the keeper of all publications sent to the Society.

7. The Council is clothed with executive authority and with the legislative powers of the Society in the intervals between its meetings; but no extraordinary act of the Council shall remain in force beyond the next following stated meeting without ratification by the Society. The Council shall have control of the publications of the Society, under provisions of the By-Laws and of resolutions from time to time adopted. They shall receive nominations for Fellows, Members, Correspondents, and Patrons, and, on approval by them, shall submit such nominations to the Society for action. They shall have power to fill vacancies *ad interim* in any of the offices of the Society not otherwise provided for.

8. *Terms of Office.*—The President and Vice-Presidents shall be elected annually. The President shall not be eligible for re-election until after an interval of three years from retirement from office. A Vice-President is eligible for re-election not more than once within such interval.

The Secretary, Treasurer, and Editor shall be eligible to re-election without limitation.

Article V

Voting and Elections

1. All elections shall be by ballot. To elect a Fellow, Member, Correspondent, or Patron, or impose any special tax, shall require the assent of nine-tenths of all persons voting.

2. Voting by letter may be allowed.

3. *Election to Membership.*—Nominations for all classes of membership must be made by two Fellows according to a form to be provided by the Council. One of these Fellows must be personally acquainted with the nominee and his qualifications for membership. The Council will submit the nominations received by them, if approved, to a vote of the Society in the manner provided in the By-Laws. The result may be announced at any stated meeting; after which notice shall be sent out to the elect.

4. *Election of Officers.*—Nominations for office shall be made by the Council or otherwise as provided for in the By-Laws. The nominations shall be submitted to a vote of the Society in the same manner as nominations for membership. The results shall be announced at the annual meeting; and the officers thus elected shall enter upon duty at the adjournment of the meeting.

Article VI

MEETINGS

1. The Society shall hold at least one stated meeting a year in the winter season. The date and place of this meeting shall be fixed by the Council, and announced each year within three months after the adjournment of the preceding winter meeting. The program of such meeting shall be determined by the Council in conjunction with the Council of the Geological Society of America and announced beforehand, in its general features. The details of the daily sessions shall be arranged by the Council of this Society.

2. The winter meeting shall be regarded as the annual meeting.

3. Special meetings of the Society as a whole or of any of its sections as sectional meetings may be called by the Council, and must be called upon the written request of ten Fellows, for a general meeting and of five Fellows for any of its sections.

4. The stated meetings of the Council shall be held coincidently with the stated meeting of the Society. Special meetings may be called by the President at such times as he may deem necessary.

5. *Quorum.*—At meetings of the Society a majority of those registered in attendance shall constitute a quorum. Four shall constitute a quorum of the Council.

Article VII

PUBLICATIONS

The publications of the Society shall be under the immediate control of the Council.

Article VIII

AMENDMENTS

1. This Constitution may be amended at any winter meeting by a three-fourths vote of all the Fellows, provided that the proposed amendment shall have been submitted in print to all Fellows at least three months previous to the meeting.

2. By-Laws may be made or amended by a majority vote of the Fellows present and voting at any annual meeting, provided that printed notice of the proposed amendment or by-law shall have been given to all Fellows at least three months before the meeting.

BY-LAWS

Chapter I

MEMBERSHIP

1. All Fellows of the Geological Society of America in good standing whose work is primarily in paleontology may, upon application to the Council of this Society, be elected without additional dues as Fellows of The Paleontological

Society. Such Fellows, if Life Members of the Geological Society, will have no further dues to pay in The Paleontological Society.

2. No person shall be accepted as a Fellow of The Paleontological Society unless he pay to the Geological Society of America the initiation fee and the dues for the year within three months after notification of his election. The initiation fee of Fellows shall be ten (10) dollars and the annual dues ten (10) dollars, payable on or before the annual meeting in advance; but a single prepayment of one hundred (100) dollars shall be accepted as commutation for life.

The annual dues for Members shall be three (3) dollars. No person shall be accepted as a Member unless he pay the dues for the year within three months after notification of his election. The annual dues are payable to The Paleontological Society on or before the annual meeting.

3. An arrearage in payment of annual dues shall deprive a Fellow or Member of the privilege of taking part in the management of the Society and of receiving the publications of the Society. An arrearage continuing over two (2) years shall be construed as notification of withdrawal.

4. Any person eligible under Article III of the Constitution may be elected Patron upon the payment of one thousand (1,000) dollars to the Society.

Chapter II

OFFICIALS

1. The President shall countersign, if he approves, all duly authorized accounts and orders drawn on the Treasurer for the disbursement of money.

2. The Secretary, until otherwise ordered by the Society, shall perform the duties of Editor, Librarian, and Custodian of the property of the Society.

3. The Society may elect an Assistant Secretary.

4. The Treasurer shall give bonds, with two good sureties approved by the Council, in the sum of one thousand dollars, for the faithful and honest performance of his duties and the safe-keeping of the funds of the Society. He may deposit the funds in bank at his discretion, but shall not invest them without authority of the Council. His accounts shall be balanced as on the thirtieth day of November of each year.

5. The minutes of the proceedings of the Council shall be subject to call by the Society.

6. The Council may transact its business by correspondence during the intervals between its stated meetings; but affirmative action by a majority of the Council shall be necessary in order to make action by correspondence valid.

Chapter III

ELECTION OF MEMBERS

1. Nominations for all classes of membership may be proposed at any time on blanks to be supplied by the Secretary.

2. The form for nomination shall be as follows:

In accordance with his desire, we respectfully nominate for Fellow, Member, Correspondent, or Patron of The Paleontological Society:
Full name; degrees; address; occupation; branch of Paleontology now engaged in; work already done and publications made.
(Signed by at least two Fellows.)

The form when filled is to be transmitted to the Secretary.

3. The Secretary will bring all nominations before the Council, at the winter meeting of the Society. The Council will signify its approval or disapproval of each, and forward to the Council of the Geological Society of America all approved nominations to Fellowship.

4. At least a month before the stated winter meeting of the Society the Secretary shall mail a printed list of all approved nominees for membership to each Fellow and Member, accompanied by such information as may be necessary for intelligent voting, but an informal list of the candidates shall be sent to each Fellow and Member at least two weeks prior to distribution of the ballots.

5. The Fellows and Members receiving the list will signify their approval or disapproval of each nominee, and return the lists to the Secretary.

6. At the next stated meeting of the Council the Secretary shall present the lists and the Council will canvass the returns.

7. The Council, by unanimous vote of the members in attendance, may still exercise the power of rejection of any nominee whom new information shows to be unsuitable for membership.

8. At the next stated meeting of the Society the Council shall declare the results.

CHAPTER IV

ELECTION OF OFFICERS

1. The Council shall prepare a list of nominations for the several offices, which list will constitute the regular ticket. This ticket must be approved by a majority of the entire Council. The nominee for President shall not be a member of the Council.

2. The list shall be mailed to the Fellows and Members, for their information, at least nine months before the annual meeting. Any five Fellows may forward to the Secretary other nominations for any or all offices. All such nominations reaching the Secretary at least 40 days before the annual meeting shall be printed, together with the names of the nominators, as special tickets. The regular and special tickets shall then be mailed to the Fellows and Members at least 25 days before the annual meeting.

3. The Fellows and Members shall send their ballots to the Secretary in double envelopes, the outer envelope bearing the voter's name. At the winter meeting of the Council, the Secretary shall bring the returns of ballots before the Council for canvass, and during the winter meeting of the Society the Council shall declare the result.

4. In case a majority of all the ballots shall not have been cast for any candidate for any office, the Society shall by ballot at such winter meeting proceed to make an election for such office from the two candidates having the highest number of votes.

CHAPTER V

FINANCIAL METHODS

1. No pecuniary obligation shall be contracted without express sanction of the Society or the Council. But it is to be understood that all ordinary, incidental, and running expenses have the permanent sanction of the Society, without special action.

2. The creditor of the Society must present to the Treasurer a fully itemized bill, certified by the official ordering it, and approved by the President. The Treasurer shall then pay the amount out of any funds not otherwise appropriated, and the receipted bill shall be held as his voucher.

3. At each annual meeting, the President shall call upon the Society to choose two Fellows or Members, not members of the Council, to whom shall be referred the books of the Treasurer, duly posted and balanced to the close of November thirtieth, as specified in the By-Laws, Chapter II, section 4. The Auditors shall examine the accounts and vouchers of the Treasurer, and any member or members of the Council may be present during the examination. The report of the Auditors shall be rendered to the Society before the adjournment of the meeting, and the Society shall take appropriate action.

Chapter VI

PUBLICATIONS

1. The publications are in charge of the Council and under its control.

2. One copy of each publication shall be sent to each Fellow, Member, Correspondent, and Patron.

Chapter VII

THE PUBLICATION FUND

The Publication Fund shall consist of donations made in aid of publication.

Chapter VIII

ORDER OF BUSINESS

1. The Order of Business at winter meetings shall be as follows:

(1) Call to order by the presiding officer.
(2) Introductory ceremonies.
(3) Report of the Council (including report of the officers).
(4) Appointment of the Auditing Committee.
(5) Declaration of the vote for officers, and election by the meeting in case of failure to elect by the Society through transmitted ballots.
(6) Declaration of the vote for Fellows.
(7) Declaration of the vote for Members.
(8) Deferred business.
(9) New business.
(10) Announcements.
(11) Necrology.
(12) Reading of scientific papers.

2. At an adjourned session the order shall be resumed at the place reached on the previous adjournment, but new business will be in order before the reading of scientific papers.

3. At any Special Meeting the order of business shall be numbers (1), (2), (3), (10), followed by the special business for which the meeting was called.

OFFICERS AND MEMBERS OF THE PALEONTOLOGICAL SOCIETY

OFFICERS FOR 1910

President:

CHARLES SCHUCHERT, New Haven, Conn.

First Vice-President:

E. O. ULRICH, Washington, D. C.

Second Vice-President:

S. W. WILLISTON, Chicago, Ill.

Third Vice-President:

F. H. KNOWLTON, Washington, D. C.

Secretary:

R. S. BASSLER, Washington, D. C.

Treasurer:

W. D. MATTHEW, New York, N. Y.

Editor:

CHARLES R. EASTMAN, Cambridge, Mass.

MEMBERS, DECEMBER 31, 1909

*Indicates the Fellows of the Society (see Article III of the Constitution, on page 77 of this volume).

*JOSÉ GUADALUPE AGUILERA, Ph. D., City of Mexico, Mexico; Director del Instituto Geologico de Mexico.

*TRUMAN H. ALDRICH, M. E., 1739 P St. N. W., Washington, D. C.

*HENRY M. AMI, A. M., Ottawa, Canada; Assistant Paleontologist, Geological and Natural History Survey of Canada.

*RALPH ARNOLD, Ph. D., 726 H. W. Hellman Bldg., Los Angeles, Cal.

*RUFUS MATHER BAGG, JR., Ph. D., 603 W. Green St., Urbana, Ill.; Instructor in Geology, University of Illinois.

*EDWIN HINCKLEY BARBOUR, Ph. D., Lincoln, Neb.; Professor of Geology, University of Nebraska, and Acting State Geologist.

*RAY SMITH BASSLER, B. A., M. S., Ph. D., Washington, D. C.; U. S. National Museum.

*JOSHUA W. BEEDE, Ph. D., Bloomington, Ind.; Instructor in Geology, Indiana University.

*Edward Wilber Berry, Baltimore, Md.; Instructor in Paleontology, Johns Hopkins University.

*Arthur B. Bibbins, Ph. B., Baltimore, Md.; Instructor in Woman's College.

Emil Böse, Ph. D., City of Mexico, Mexico; Instituto Geologico de Mexico.

Barnum Brown, New York, N. Y.; Assistant Curator of Fossil Reptiles, American Museum of Natural History.

Carl Burckhardt, Ph. D., City of Mexico, Mexico; Instituto Geologico de Mexico.

*Samuel Calvin, Ph. D., LL. D., Iowa City, Iowa; State Geologist; Professor of Geology, State University of Iowa.

*Ermine C. Case, Ph. D., Ann Arbor, Mich.; Department of Geology, University of Michigan.

*William Bullock Clark, Ph. D., Baltimore, Md.; Professor of Geology, Johns Hopkins University; State Geologist.

*John Mason Clarke, A. M., Albany, N. Y.; State Paleontologist.

*Herdman F. Cleland, Ph. D., Williamstown, Mass.; Professor of Geology, Williams College.

Harold J. Cook, Agate, Neb.

*Edgar R. Cumings, Ph. D., Bloomington, Ind.; Professor of Geology, Indiana University.

W. H. Dall, A. M., Sc. D., Smithsonian Institution, Washington, D. C.; Paleontologist, U. S. Geological Survey.

Bashford Dean, Ph. D., New York, N. Y.; Professor of Vertebrate Zoölogy, Columbian University.

*Orville A. Derby, M. S., 80 Rua Visconde do Rio Branco, Sao Paulo, Brazil.

*Charles R. Eastman, A. M., Ph. D., Cambridge, Mass.; In charge of Vertebrate Paleontology, Museum of Comparative Zoölogy, Harvard University.

George F. Eaton, A. B., Ph. D., 80 Sachem St., New Haven, Conn.; Associate Curator of Invertebrate Paleontology, Yale University.

*August F. Foerste, Ph. D., 417 Grand Ave., Dayton, Ohio; Teacher of Sciences, Steele High School.

*William M. Fontaine, A. M., Charlettesville, Va.; Professor of Natural History and Geology, University of Virginia.

Charles Newton Gould, A. M., Norman, Okla.; Professor of Geology, University of Oklahoma.

*Amadeus W. Grabau, S. M., S. D., New York, N. Y.; Professor of Paleontology, Columbia University.

*Gilbert D. Harris, Ph. B., Ithaca, N. Y.; Assistant Professor of Paleontology and Stratigraphic Geology, Cornell University.

William J. Holland, A. B., Ph. D., D. D., Sc. D., LL. D., Pittsburgh, Pa.; Director, Carnegie Museum.

*Arthur Hollick, Ph. B., Bronx Park, New York, N. Y.; Assistant Curator, Department of Fossil Botany, New York Botanical Garden.

George H. Hudson, 19 Broad St., Plattsburgh, N. Y.; In Charge of Science, State Normal School.

Louis Hussakof, B. S., Ph. D., New York, N. Y.; Assistant Curator of Fossil Fishes, American Museum of Natural History.

*Robert T. Jackson, S. D., 9 Fayerweather St., Cambridge, Mass.; Assistant Professor in Paleontology, Harvard University.

EDWIN KIRK, Washington, D. C.; U. S. Geological Survey.

*EDWARD M. KINDLE, Ph. D., Washington, D. C.; Assistant Geologist, U. S. Geological Survey.

*FRANK H. KNOWLTON, M. S., U. S. National Museum, Washington, D. C.; Assistant Paleontologist, U. S. Geological Survey.

*FREDERIC BREWSTER LOOMIS, B. A., Ph. D., Amherst, Mass.; Professor of Comparative Anatomy in Amherst College.

*RICHARD SWANN LULL, B. S., M. S., Ph. D., New Haven, Conn.; Associate Curator in Vertebrate Paleontology, Yale University.

D. D. LUTHER, Naples, N. Y.

THOMAS H. MACBRIDE, A. B., A. M., Ph. D., Iowa City, Iowa; Professor of Botany, University of Iowa.

GEORGE FREDERIC MATTHEW, A. M., Sc. D., LL. D., 88 Summer St., St. John, N. B., Can.; Surveyor of Customs of Canada.

*W. D. MATTHEW, Ph. D., New York, N. Y.; Associate Curator of Vertebrate Paleontology, American Museum of Natural History.

*JOHN C. MERRIAM, Ph. D., Berkeley, Cal.; Instructor in Paleontology, University of California.

*HENRY F. OSBORN, Sc. D., New York, N. Y.; President, American Museum of Natural History.

*WILLIAM A. PARKS, A. B., Ph. D., Toronto, Canada; Associate Professor of Geology, University of Toronto.

*DAVID PEARCE PENHALLOW, B. S., M. S., Sc. D., Montreal, Canada; Professor of Botany, McGill University.

*CHARLES S. PROSSER, M. S., Columbus, Ohio; Professor of Geology, Ohio State University.

*PERCY EDWARD RAYMOND, B. A., Ph. D., Pittsburgh, Pa.; Assistant Curator of Invertebrate Fossils, Carnegie Museum.

R. R. ROWLEY, Louisiana, Mo.

*RUDOLPH RUEDEMANN, Ph. D., Albany, N. Y.; Assistant State Paleontologist.

*FREDERICK W. SARDESON, Ph. D., Minneapolis, Minn.; Assistant Professor of Geology, University of Minnesota.

*THOMAS EDMUND SAVAGE, A. B., B. S., M. S., Urbana, Ill.; Department of Geolgoy, University of Illinois.

*CHARLES SCHUCHERT, New Haven, Conn.; Professor of Paleontology, Yale University.

*WILLIAM B. SCOTT, Ph. D., 56 Bayard Ave., Princeton, N. J.; Blair Professor of Geology, Princeton University.

*HENRY M. SEELY, M. D., Middlebury, Vt.; Professor of Geology, Middlebury College.

*ELIAS H. SELLARDS, Ph. D., Tallahassee, Fla.; State Geologist.

HERVEY W. SHIMER, A. B., A. M., Ph. D., Boston, Mass.; Instructor in Geology, Massachusetts Institute of Technology.

*WILLIAM JOHN SINCLAIR, B. S., Ph. D., Princeton, N. J.; Instructor in Princeton University.

BURNETT SMITH, Ph. D., Syracuse, N. Y.; Department of Geology, Syracuse University.

J. PERRIN SMITH, A. B., A. M., Stanford University, Cal.; Professor of Paleontology and Mineralogy, Stanford University.

FRANK SPRINGER, Ph. B., Las Vegas, N. Mex.

*TIMOTHY WILLIAM STANTON, B. S., U. S. National Museum, Washington, D. C.; Assistant Paleontologist, U. S. Geological Survey.

*CHARLES KEPHART SWARTZ, A. B., Ph. D., Baltimore, Md.; Associate Professor of Geology, Johns Hopkins University.

MIGNON TALBOT, A. B., Ph. D., South Hadley, Mass.; Head of Department of Geology, Mt. Holyoke College.

*EDWARD O. ULRICH, D. Sc., Washington, D. C.; Assistant Geologist, U. S. Geological Survey.

*GILBERT VAN INGEN, Princeton, N. J.; Curator of Invertebrate Paleontology, and Assistant in Geology, Princeton University.

*THOMAS WAYLAND VAUGHAN, B. S., A. M., Washington, D. C.; Assistant Geologist, U. S. Geological Survey.

*ANTHONY W. VOGDES, 2425 First St., San Diego, Cal.; Brigadier General, U. S. A. (Retired).

*CHARLES D. WALCOTT, LL. D., Washington, D. C.; Secretary, Smithsonian Institution.

*STUART WELLER, B. S., Chicago, Ill.; Associate Professor of Paleontologic Geology, University of Chicago.

*DAVID WHITE, B. S., U. S. National Museum, Washington, D. C.; Geologist, U. S. Geological Survey.

*ROBERT P. WHITFIELD, A. M., New York, N. Y.; Curator Emeritus of Geology and Invertebrate Paleontology, American Museum of Natural History.

*HENRY S. WILLIAMS, Ph. D., Ithaca, N. Y.; Professor of Geology and Head of Geological Department, Cornell University.

*SAMUEL W. WILLISTON, Ph. D., M. D., Chicago, Ill.; Professor of Paleontology, University of Chicago.

JOHN D. WILSON, Syracuse University, Syracuse, N. Y.

ELVIRA WOOD, New York, N. Y.; Department of Geology, Columbia University.

MEMBERS-ELECT, DECEMBER 31, 1909

ROBERT ANDERSON, U. S. Geological Survey, Washington, D. C.

F. C. CLARK, Los Angeles, Cal.

C. O. ESTERLY, Occidental College, Los Angeles, Cal.

E. L. FURLONG, University of California, Berkeley, Cal.

G. S. GESTER, Assistant Geologist, Southern Pacific Railway Co., San Francisco, Cal.

HUGH GIBB, Peabody Museum, Yale University, New Haven, Conn.

J. Z. GILBERT, Los Angeles High School, Los Angeles, Cal.

ROBERT H. GORDON, Cumberland, Md.

C. A. HARTNAGEL, State Hall, Albany, N. Y.

JESSE E. HYDE, Columbia University, New York, N. Y.

L. H. MILLER, State Normal School, Los Angeles, Cal.

R. L. MOODIE, University of Kansas, Lawrence, Kas.

WILLIAM CLIFFORD MORSE, Ohio State University, Columbus, Ohio.

R. W. PACK, University of California, Berkeley, Cal.

CLINTON RAYMOND STAUFFER, Geological Survey of Ohio, Columbus, Ohio.

CHARLES H. STERNBERG, Lawrence, Kas.

EDGAR E. TELLER, 3321 Sycamore St., Milwaukee, Wis.

JACOB VAN DELOO, State Hall, Albany, N. Y.

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
VOL. 21, PP. 87-118 MARCH 31, 1910

ORIGIN OF THE ALKALINE ROCKS[1]

BY REGINALD A. DALY

(Presented in abstract before the Society December 30, 1909)

CONTENTS

	Page
Definition	87
General statement of the investigation	88
Association of alkaline and subalkaline rocks	89
Alkaline rocks genetically connected with subalkaline magmas	90
Association of alkaline rocks with limestones, dolomites, and other calcareous sediments	91
Table showing field associations of alkaline and subalkaline eruptives and calcareous sediments	92
Effects of the solution of carbonates in subalkaline magma	108
Additional evidences favoring the hypothesis	110
Possible objections to the hypothesis	111
Alkaline rocks not associated with calcareous sediments	113
General conclusions	114

DEFINITION

Alkaline rocks include two classes: first, those relatively rich in soda, in potash, or in both; and, secondly, those which, with relatively low total of alkalies, yet carry essential amounts of minerals specially characteristic of alkali-rich eruptives, such as nephelite, leucite, analcite, etcetera. Field (genetic) association is also a criterion generally used in separating any alkaline type from the subalkaline or lime-alkali group of igneous rocks. Thus, monzonite may not be rich in alkalies nor carry any feldspathoid, yet it is regarded as of the alkaline group largely because it is often in comagmatic relation to nephelite syenite or the alkaline feldspar syenites. For the same reason, camptonite, alnöite, limburgite, and melilite basalt with, on the average, only 4.1 to 5.4 per cent of alkalies for each, are considered as belonging in the alkaline groups, though no feldspathoid is an essential constituent of any one of these rocks. On the

[1] Manuscript received by the Secretary of the Society January 4, 1910.

other hand, liparite and dacite, with average alkalies of, respectively, 7.6 and 6.6 per cent, are placed in the subalkaline group because of their common independence of the nephelite syenites, phonolites, leucitic rocks, etcetera, in field occurrence. No single principle compels the separation of the two groups, and the difficulty of making it sharp is enhanced by the fact that there are plenty of rock species transitional between ideal alkaline types and standard types of the subalkaline group. Nevertheless, the separation so far actually made by Rosenbusch, Iddings, Loewinson-Lessing, Harker, and many others is about as definite as some of the divisions among the subalkaline rocks. For this paper the question as to how far the distinction is objective and justifiable need not be answered, though it will be seen that there are grounds for believing in a very close genetic connection between the two groups.

General Statement of the Investigation

This major classification of igneous rocks immediately raises the question of origins. Why are the alkalies concentrated in certain types of igneous rocks? Why are many alkaline rocks so low in silica that feldspathoids form instead of feldspar? In many petrographic memoirs their authors have assumed that each alkaline comagmatic region is underlain by one or more reservoirs of magma which was rich in alkalies from "the foundation of the world." The visible eruptives are regarded as differentiates from such primeval segregations. A few writers have suggested the derivation of alkaline types from subalkaline magma by unusual processes of differentiation. No one has yet stated the conditions for this special differentiation. The succeeding pages bear an outline of a hypothesis intended in some degree to declare those conditions.

It will first be pointed out that no alkaline province can be described as free from subalkaline eruptives, especially those of basaltic or granitic types. Emphasis will be laid on the indisputable fact that the visible volume of all alkaline rock bodies is a very minute quantity as compared with the visible volume of subalkaline eruptive bodies. An inductive study shows that most alkaline rocks cut thick masses of limestones, dolomites, or other calcareous sediments. This fact suggests the hypothesis that the absorption of carbonate disturbs the chemical equilibrium of subalkaline magma in such manner that alkaline fractions are produced by differentiation. Most of the alkaline species are ascribed to the interaction of basaltic magma and limestone, but more acid magma is also sensitive to the solution of carbonate. The hypothesis explains the concentration of alkalies; the desilication shown by the crystallization of

nephelite, leucite, corundum, etcetera; the extreme variability of alkaline bodies in mineralogical and chemical composition; the occurrence of such lime-bearing minerals as melilite, scapolite, wollastonite, melanite, etcetera, and such CO_2-bearing minerals as cancrinite and (primary) calcite. The difficult problem remains as to the physico-chemical reactions involved in the hypothesis. This paper is offered as an advertisement of the need for help from the physical chemists in giving a final explanation of the described geological facts of rock-association. The writer is indebted to Dr. H. S. Washington for helpful, though adverse, criticism.

Association of alkaline and subalkaline Rocks

In most alkaline provinces typical basalts, diabases, gabbros, diorite, andesite, (post-Archean) granite, or other common lime-alkali eruptives occur. From the character and distribution of the visible pre-Cambrian terrane, it is in the highest degree probable that its granite or greenstone exists at greater or less depth in some part of each alkaline province on the continental plateaus. This steady association is partly illustrated in the following table, which is far from being exhaustive even as regards the post-Archean eruptives. Very often alkaline and subalkaline types are represented in the same petrogenic cycle and province. A few examples may be extracted from the table. The gabbro (with diorite) and diabase of Ascutney Mountain, Vermont, respectively open and close the eruptive series, which includes nordmarkite, paisanite, alkaline granite, camptonite, etcetera. The trachyte (acid phonolite) of Hawaii cuts, and is overflowed by, olivine basalt; the nephelite basalt of Oahu is interbedded with feldspar basalts. Feldspar basalts, with phonolites, compose Kerguelen, Fernando Noronha, Saint Helena, and other islands.

Whether associated alkaline and subalkaline rocks are products of one petrogenic cycle or have been erupted at long intervals of geological time, it is hard, if not impossible, to conceive that the alkaline bodies are offshoots from primeval reservoirs of foyaitic or other magma rich in soda and potash. This conception has held its place in petrology so long because of a systematic ignoring of the association described. The mind fails to grasp the intercrustal or subcrustal conditions which permit of the independent existence of initially alkaline and subalkaline magma chambers beneath the same, generally quite limited, areas of the earth's surface.

The conception is further at fault in not allowing for the comparatively minute volume of all the alkaline-rock bodies now known on the globe. The largest alkaline plutonic mass yet described is doubtless the

nephelite syenite "laccolith" of the Kola Peninsula, with an estimated area of 1,600 square kilometers. The Kangerdluarsuk (Greenland) nephelite syenite covers 390 square kilometers. The Bancroft (Ontario) nephelite syenite covers about 25 square kilometers. These figures show the order of magnitude of the largest intrusive alkaline bodies. The alkaline extrusives are yet more numerous, but are generally of much smaller volume than any of these plutonic masses. The visible alkaline rock of an average locality covers but a few square kilometers, and its reasonably inferred volume is only a few cubic kilometers. All the visible alkaline rock of the world probably constitutes less than one per cent of the total visible igneous rock. The visible volume of the subalkaline Coast Range batholith of British Columbia and Alaska, covering at least 150,000 square kilometers, is doubtless much greater than that of all the world's known alkaline bodies put together.

There seems to be no reason to doubt that the size of the erupted bodies will be, on the average, in direct proportion to the size of the feeding magma chambers. If each chamber be a primeval alkaline reservoir, it has, accordingly, a very small size as compared with the known bodies of subalkaline granite or basalt. We are led to the deduction that relatively and absolutely small bodies of magma can conserve the heat appropriate to fluidity for scores of millions of years. Simple calculation and common sense show that this is an impossible supposition. If we turn on our tracks and deny the smallness of the alkaline-magma reservoirs we face a dilemma as clearly unacceptable to the field geologist.

Alkaline Rocks genetically connected with subalkaline Magmas

If subalkaline magma alone carries enough primary heat to be eruptible, it follows that alkaline magmas are either differentiates from subalkaline magma or syntectics,[2]—that is, solutions of foreign rock in subalkaline magma—or differentiates from such syntectics. For the first and third of these hypotheses the observed field association of the two rock groups, the relative volume of each group, and the chemical composition of the alkaline types are all more or less appropriate. We have seen that many subalkaline rocks actually carry more alkalies than some "alkaline" rocks. The extreme case of associated phonolite and basalt may be briefly discussed in preference. Average phonolite (calculated as water-free) carries about 9.0 per cent of soda and 5.3 per cent of potash. Average basalt (calculated as water-free) carries about 3.2 per cent of soda and 1.6 per

[2] This word is adapted from Loewinson-Lessing. Compte Rendu, 7e session, Congrès géologique internationale, Saint Petersburg, 1899, p. 375.

cent of potash. If alkalies sufficient for one volume of phonolite were concentrated from twenty volumes of basalt, the residual magma would still have a composition little different from that of average basalt. The total volume of the known phonolites is surely not more than five per cent of the known volume of extruded basalt. Much slighter concentration of the alkalies from basalt would give the soda and potash appropriate to trachydolerite, tephrite, or basanite. These illustrations show that there is no violence done to the principle of magmatic differentiation in making it responsible for the derivation of alkaline rocks from subalkaline magmas. That derivation is further suggested by the numerous transitions observed between alkaline and subalkaline rocks.

Why is the eruptive sequence of subalkaline magmas ever broken? What is the cause of the concentration of their alkalies so that at certain times and places relatively small eruptions of alkaline magmas occur? The attempt to answer these questions is the central theme of this paper.

Association of alkaline Rocks with Limestones, Dolomites, and other calcareous Sediments

The following table gives a summary statement of the facts from which a general rule connecting alkaline igneous rocks and calcareous sediments may be deduced. With but few exceptions, if any, the magmas from which these eruptive rocks were derived cut limestone, dolomite, or other deposits containing notable proportions of carbonate.[3]

The sources of information used in making the table were reached chiefly through the lists of references published in the fourth edition of Rosenbusch's "Mikroskopische Physiographie der Massigen Gesteine." It was found that most of the petrographic papers give few facts regarding the formations cut by the alkaline eruptives. In many instances the more purely geological reports, memoirs, and maps have given valuable data on the subject. These additional references are usually the obvious ones; to keep this paper within a proper limit of size, they are not listed. The table is not complete, though it contains names of nearly all the important alkaline-rock districts now known on the globe.

In constructing the fourth column, it was often necessary to search for information as to the sedimentary terranes underlying the present land surface in the districts. Care was taken to assume limestone below the surface only when the facts pointed strongly in that direction. It was

[3] A remarkable illustration is found in the great nephelite syenite fields of eastern Ontario, where the foyaitic phase of the pre-Cambrian granitic batholiths is found at contacts with limestone. F. D. Adams and A. E. Barlow, Transactions of the Royal Society of Canada, third series, vol. 2, section 4, 1909, p. 8.

sometimes clear, too, that limestones were present in the roofs of alkaline intrusives of the stock or batholith order, and it is then legitimate to consider such limestone as subject to stoping and abyssal assimilation during intrusion. The blanks in the third column mean lack of information and not necessarily absence of subalkaline eruptions in the corresponding districts.

TABLE SHOWING FIELD ASSOCIATIONS OF ALKALINE AND SUBALKALINE ERUPTIVES AND CALCAREOUS SEDIMENTS

NORTH AMERICA

Region.	*Alkaline eruptives.*	*Associated subalkaline eruptives.*	*Carbonate rocks cut by alkaline eruptives.*
Bancroft, Ontario.	Nephelite syenite.	Anorthosite, granite, etcetera.	Grenville limestone.
Monteregian Hills, Quebec.	Theralite, essexite, pulaskite, nordmarkite, nephelite syenite, camptonite, bostonite, tinguaite, sölvsbergite, fourchite, monchiquite, alnöite.	Gabbro, diabase, etcetera.	Chazy, Trenton, and Devonian limestones. Pre-Cambrian limestone. ?
Ottawa Valley, Quebec.	Shonkinite.	Granite, diabase, pyroxenite, etcetera.	?
Pooh-bah Lake, Ontario.	Malignite.	Diabase, granite, etcetera.	?
Port Coldwell, Ontario.	Nephelite syenite.	Gabbro.	?
Heron Bay, Ontario.	Heronite.	Diabase.	?
North-central Wisconsin.	Nephelite syenite, etcetera.	Gabbro, diorite, granite, etcetera	? Calcareous graywacke, chert, shale, and slate in older terrane.
Southwest Alaska.	Leucite phonolite.	Granodiorite, etcetera.	Paleozoic limestones beneath Jurassic series.

Table showing Field Associations of Alkaline and Subalkaline Eruptives—Continued.

Region.	*Alkaline eruptives.*	*Associated subalkaline eruptives.*	*Carbonate rocks cut by alkaline eruptives.*
Ice River, British Columbia.	Nephelite syenite, ijolite, cancrinite syenite, urtite, tinguaite.		Limestones and dolomites of Beltian, Cambrian, Devonian (?), and Carboniferous (?).
Kruger Mountain, British Columbia.	Nephelite syenite, malignite.	Granodiorite, gabbro, andesites, peridotites, etcetera.	Paleozoic limestone (?).
Kettle River, British Columbia.	Rhomb porphyry, analcitic rhomb-porphyry, alkaline trachyte.	Basalt, andesites, gabbros, etcetera.	Paleozoic limestone (?).
Rossland, British Columbia.	Monzonite, latites, missourite.	Basalts, andesites, gabbros, etcetera.	Carboniferous limestone.
Salmon River, British Columbia.	Monzonite.	Granite, basalt, andesites, etcetera.	Thick Paleozoic limestones.
Bearpaw Mountains, Montana.	Leucite basalt, mica-trachyte, shonkinite, monzonite, augite syenite, nephelite basalt, leucitite, tinguaites.		Paleozoic and Mesozoic limestones and dolomites.
Highwood Mountains, Montana.	Syenites, monzonite, shonkinite, fergusite, missourite, trachy-andesite, gautëite, leucite shonkinite, analcite basalt, minette.	Basalt, diorite, granite porphyry, granite, etcetera.	Paleozoic and Mesozoic limestones and dolomites.
Judith Mountains, Montana.	Tinguaites (augite phonolites).	Diorite and granite, porphyries, etcetera	Ditto.

Table showing Field Associations of Alkaline and Subalkaline Eruptives—Continued.

Region.	*Alkaline eruptivs.*	*Associated subalkaline eruptives.*	*Carbonate rocks cut by alkaline eruptives.*
Little Belt Mountains, Montana.	Syenite, monzonite, shonkinite, analcite basalts, vogesites, minettes.	Basalt, diorite, and granite.	Ditto; also some Beltian (Belt terrane) limestones.
Castle Mountains, Montana.	Theralite, acmite trachyte.	Ditto.	Ditto.
Crazy Mountains, Montana.	Theralite, acmite trachyte.	Diorite, granite, etcetera.	Ditto.
Cœur d'Alene district, Idaho.	Monzonites.	Diabase.	Limestone, dolomite, and calcareous argillites of Belt terrane.
Goldfield, Nevada.	Monzonite porphyry and latite.	Basalt, andesite, rhyolite, etcetera.	Cambrian limestone and calcareous shale.
Tintic, Utah.	Monzonite.		Carboniferous limestones.
Yellowstone Park.	Monzonite, syenite, absarokite, shoshonite.	Liparite, granite, diorite, etcetera.	Paleozoic limestones.
Sundance Quadrangle, Wyoming-South Dakota.	Monzonite, leucite porphyry, nephelite syenite, bostonite, ijolite, nephelinite, fourchite, camptonite, vogesite, pyroxenite.		Paleozoic limestones.
Aladdin Quadrangle, Wyoming-South Dakota-Montana.	Suite including some types of Sundance list.		Ditto.
Leucite Hills, Wyoming.	Wyomingite, orendite, madupite.	Granite.	Paleozoic and Mesozoic limestones.

Table showing Field Associations of Alkaline and Subalkaline Eruptives—Continued.

Region.	*Alkaline eruptives.*	*Associated subalkaline eruptives.*	*Carbonate rocks cut by alkaline eruptives.*
Black Hills, South Dakota.	Phonolite, grorudite.	Diorite, liparite.	Ditto.
Denver Basin, Colorado.	Trachydolerite.		Mesozoic limestones of four horizons.
Rico District, Colorado.	Monzonite.		Paleozoic limestones
La Plata Quadrangle, Colorado.	Monzonite.		Paleozoic and Jurassic limestones, calcareous sandstones, etcetera.
Telluride Quadrangle, Colorado.	Monzonite.		Ditto.
Georgetown Quadrangle, Colorado.	Alkali syenite porphyry, latite, bostonite, etcetera.	Diorite, granite, etcetera.	Pre-Cambrian limestone.
Cripple Creek District, Colorado.	Phonolite, latite-phonolite, syenite, trachydolerite, vogesite, monchiquite.	Granite, olivine syenite, anorthosite, diabase	?
Spanish Peaks, Colorado.	Monzonite porphyry.		Mesozoic and probably Paleozoic limestones and calcareous shales.
Magnet Cove, Arkansas.	Nephelite syenite, ijolite, shonkinite, leucite porphyry, tinguaite, monchiquite, jacupirangite.		Paleozoic magnesian limestones.
Walsenburg Quadrangle, New Mexico.	Monzonite porphyry.		Ditto.

Table showing Field Associations of Alkaline and Subalkaline Eruptives—Continued.

Region.	*Alkaline eruptives.*	*Associated subalkaline eruptives.*	*Carbonate rocks cut by alkaline eruptives.*
Pilot Knob, Texas.	Nephelite basalt.		Cretaceous (and older ?) limestones.
Apache Mountains, Texas.	Nephelite syenite, other syenites, tinguaite, bostonite, paisanite, phonolite.		Paleozoic and Mesozoic limestones.
Uvalde County, Texas.	Melilite - nephelite basalt, nephelite basanite, phonolite, nephelite basalt, limburgite.	Plagioclase basalt.	Mesozoic (and older ?) limestones and marls.
Big Trees Quadrangle, California.	Latites.	Granodiorite, andesites, basalt, etcetera.	Paleozoic limestones and clay slates.
Mother Lode District, California.	Latites.	Ditto.	Ditto.
Point Sal, California.	Teschenite.		Tertiary limestones and clays; Cretaceous shales.
San Luis Obispo County, California.	Analcite diabase.		Ditto.
Beemerville, New Jersey.	Nephelite syenite.	Diabase, etcetera.	Lower Paleozoic dolomitic limestones. (Also pre-Cambrian limestones ?)
Brockville, New Jersey.	Nephelite syenite.	Diabase.	Pre-Cambrian limestone adjacent.
Adirondack Mountains, New York.	Alkaline syenite.	Anorthosite, granite, etcetera.	Grenville limestone.

Table showing Field Associations of Alkaline and Subalkaline Eruptives—Continued.

Region.	*Alkaline eruptives.*	*Associated subalkaline eruptives.*	*Carbonate rocks cut by alkaline eruptives.*
Essex County, Massachusetts.	Foyaite, essexite, tinguaite, pulaskite, akerite, sölvsbergite, nordmarkite, keratophyre, paisanite, alkaline granites.	Diabase, diorite, gabbro, etcetera.	Lower Cambrian limestones and calcareous argillite. (Also younger and older limestones?)
Red Hill, New Hampshire.	Foyaite, umptekite, paisanite, bostonite, camptonite, etcetera.	Granites, etcetera.	? (Paleozoic limestones in roof now eroded away?).
Mount Ascutney, Vermont.	Alkaline syenites, etcetera.	Diabase, diorite, gabbro.	Marbles and "Calciferous Mica Schist."
Litchfield, Maine.	Nephelite syenite, bearing much cancrinite.		? not in place. Syenite.
San José District, Mexico.	Nephelite syenite, camptonite.	Basalt, andesite.	Cretaceous limestone.
Costa Rica.	Theralite.		Tertiary (and older?) limestones.
	SOUTH AMERICA		
Sao Paulo, Brazil.	Nephelinite, teschenite, vogesite, jacupirangite, foyaite, augite syenite, laurvikite, augitite, limburgite.	Diabase, diorite.	Paleozoic limestone in clay-slates, etcetera. (Also pre-Cambrian limestones?)
Caldas, etcetera, Brazil.	Foyaite, phonolite, leucitophyre.		?
Paraguay.	Phonolite, limburgite.		?
Salta Province, Argentine.	Trachydolerite, essexite.		?
San Juan Province, Argentine.	Nephelite basalt, essexite, trachyte-tephrite, limburgite.	Feldspar basalt, andesites, dacite, etcetera.	Paleozoic (?) and Jurassic limestones.

EUROPE

Table showing Field Associations of Alkaline and Subalkaline Eruptives—Continued.

Region.	*Alkaline eruptives.*	*Associated subalkaline eruptives.*	*Carbonate rocks cut by alkaline eruptives.*
Loch Borolan, Scotland.	Foyaite, pulaskite, borolanite.		Lower Paleozoic dolomites and limestones.
Eildon and Garlton Hills, Scotland.	Phonolite-trachyte, phonolite.		?
Pouzac, Pyrenees.	Nephelite syenite, bostonite, etcetera.	Diabase.	Jurassic and Cretaceous limestones and calcareous breccias.
Velay, France.	Phonolite, trachyte.	Basalt, andesite.	Tertiary marls, limestone, with gypseous beds.
Fortuna, Spain.	Fortunite, jumillite, trachyte.		Tertiary marls, Cretaceous limestones. (Older limestones?)
Catalonia, Spain.	Nephelite basanite, limburgite.	Olivine basalt.	Tertiary and older limestones.
Serra de Monchique, Portugal.	Nephelite syenite, pulaskite, bostonite, tinguaites, monchiquite, camptonite.	Diabase.	Pre-Culm limestones.
Cezimba, Fonte da Bica, etcetera, Portugal.	Teschenite.	Diabase.	Cretaceous and older limestones.
Italian districts as under: Vulsinian, Ciminian, Sabatinian, Latian, Hernican, Auruncan, Campanian, Vesbian, Phlegrean, Mount Vulture, Tuscan, Venetian, Apulian (named by H. S. Washington).	Trachytes, leucite phonolites, leucite trachytes, leucite tephrites, latites, leucitites, leucite basanites, vulsinites, melilitic leucitites, etcetera.		Mesozoic and Tertiary limestones and dolomites. (Also Paleozoic limestones?)

Table showing Field Associations of Alkaline and Subalkaline Eruptives—Continued.

Region.	*Alkaline eruptives.*	*Associated subalkaline eruptives.*	*Carbonate rocks cut by alkaline eruptives.*
Predazzo, Tyrol.	Nephelite syenite, essexite, shonkinite, theralite, monzonite, tinguaite, camptonite, monchiquite, etcetera.	Melaphyre, etcetera.	Triassic dolomite. (Also older limestones?)
Monzoni, Tyrol.	Monzonite, essexite, alkaline syenites, tinguaites, etcetera.		Ditto.
Kaiserstuhl, Baden.	Phonolite, nephelite basalt, limburgite, leucite basalt, tephrite, leucite, phonolite, etcetera.		Mesozoic and Tertiary limestones, dolomites, and marls.
Haardt Mountains, Elsass; Mainz basin, etcetera.	Limburgite.		Muschelkalk and older and younger limestones.
Katzenbuckel, Baden.	Nephelite basalt, shonkinite, theralite, etcetera.		Mesozoic limestones and dolomites.
Hegau, Baden.	Nephelite basalt, melilite-nephelite basalt, melilite basalt, phonolite.	Feldspar basalt.	Ditto.
Suabian Alp.	Melilite basalt.		Ditto.
Siebengebirge.	Essexite, trachydolerite, monchiquite, trachyte, etcetera.		Devonian calcareous graywacke and older sediments.
Eifel.	Leucite basalt, nephelite basalt (bearing melilite), phonolite.		Ditto.
Vordereifel.	Ditto.		Ditto.

Table showing Field Associations of Alkaline and Subalkaline Eruptives—Continued.

Region.	*Alkaline eruptives.*	*Associated subalkaline eruptives.*	*Carbonate rocks cut by alkaline eruptives.*
Westerwald.	Phonolite.		Devonian limestone adjacent.
Weser-Werra-Fulda District.	Nephelite basalt, leucite basalt, melilitic nephelite basalts.	Feldspar basalt.	Mesozoic limestones and marls and Paleozoic calcareous sediments.
Rhön.	Phonolite, trachyte, nephelite basalt (often leucititic), limburgites, basanites.	Feldspar basalt.	Ditto.
Vogelsberg.	Nephelite basalt, phonolite, trachyte.	Anamesite, basalt.	Ditto.
Duppau Hills, Bohemia.	Phonolite, leucite basalt, leucitite, leucite tephrite, leucite basanite, nephelite basalt, nephelinite, nephelite tephrite, limburgite, augitite, nephelite syenite, augite syenite, theralite.	Feldspar basalt, andesite.	Tertiary marls and calcareous tuffs.
Mittelgebirge, Bohemia.	Phonolite, tephrite, essexite, sodalite syenite, trachyte, nephelite basalt, limburgite, melilite basalt.	Feldspar basalt.	Mesozoic and Paleozoic limestones and marls.
Steiermark, Austria.	Nephelite basanite, nephelinite, nepelite basalt.		Tertiary, Mesozoic (and older?) limestones and marls.
Ditro, Hungary.	Nephelite syenite (many phases)		Limestones in phyllitic terrane. (Also younger limestones?)

Table showing Field Associations of Alkaline and Subalkaline Eruptives—Continued.

Region.	*Alkaline eruptives.*	*Associated subalkaline eruptives.*	*Carbonate rocks cut by alkaline eruptives.*
Azof, Russia.	Mariupolite, orthophyre, grorudite, pyroxenite, etcetera.	Basalt, diabase.	? Paleozoic (Devonian and Carboniferous) limestones?
Miask and Kussa, Russia.	Nephelite syenite, cancrinite syenite, corundum syenite.	Granite.	Crystalline limestone adjacent.
Kuusano Parish, Finland.	Nephelite syenite, ijolite.		?
Kuolajärvi, Finland.	Cancrinite syenite.		?
Kola Peninsula, Russia.	Nephelite syenite, urtite, lujaurite, umptekite, chibinite, etcetera.	Augite porphyrite, granites.	Devonian (?) marly clay-slates. (Also limestone?)
Alnö, Sweden.	Foyaite, ijolite, jacupirangitic phases, bostonite, alnöite, etcetera.	Granite.	Crystalline limestone.
Elfdalen, Sweden.	Cancrinite tinguaite.	Quartz porphyry, augite porphyrite, etcetera.	Paleozoic limestones?
Gran, Norway.	Bostonite, camptonite.	"Olivine-gabbro-diabases," pyroxenite, hornblendite.	Paleozoic limestones, including Étages 1 to 3.
Christiania, Norway.	Essexites, akerites, laurvikites, monzonites, laurdalite, pulaskite, nordmarkite, ekerite, camptonite, rhomb-porphyry, etcetera.	Granite, diabase, etcetera.	Paleozoic limestones (and argillites).

Table showing Field Associations of Alkaline and Subalkaline Eruptives—Continued.

AFRICA.

Region.	*Alkaline eruptives.*	*Associated subalkaline eruptives.*	*Carbonate rocks cut by alkaline eruptives.*
Kamerun, Africa.	Monzonite, keratophyre, bostonite, camptonite, vogesite, leucitite, etcetera.	Diabase, diorite, etcetera.	Cretaceous (and older?) limestones.
Niger-Benué area, West Africa.	Foyaite.		Limestone of unknown age.
Ahaggar, Central Africa.	Phonolite.	Basalt, granite.	?
Aïr, Central Africa.	Phonolite, alkaline trachyte.	Granite, rhyolite.	Silurian limestones; (Cretaceous marls ?; other limestones ?)
Great Rift Valley, East Africa.	Phonolites, comendites, trachytes, kenites, nephelinites (bearing melilite), borolanite, nephelite basalt, limburgite, tephrite, nephelite basanite, leucite basanite.	Olivine basalt.	? Crystalline limestones of gneissic plateau; calcareous sandstone, conglomerate and shales of Paleozoic ?
Abyssinia.	Phonolites, tinguaites, grorudite, paisanite, sölvsbergite, etcetera.	Olivine basalt, diabase, gabbro, diorite, etcetera.	Thick crystalline limestones and dolomites in gneissic plateau; also Jurassic and younger limestones.
Bushveld, South Africa.	Nephelite syenite, monchiquite, camptonite, bostonite, etcetera.	Norite, gabbro, granite, etcetera.	The Great Dolomite.
Marico, Transvaal.	Nephelite syenites.	Norite, gabbro.	Ditto.

Table showing Field Associations of Alkaline and Subalkaline Eruptives—Continued.

ASIA.

Region.	*Alkaline eruptives.*	*Associated subalkaline eruptives.*	*Carbonate rocks cut by alkaline eruptives*
Aden peninsula.	Phonolite, trachytes.		Cretaceous limestone? Older limestones?
Northern Syria.	Nephelite basanite, limburgite.	Feldspar basalt.	Cretaceous limestones.
Kula, Asia Minor.	Kulaite (trachydolerite), leucite kulaite.	Diabase, diorite, etcetera.	Tertiary (and older?) limestones.
Madras, India.	Nephelite syenites, augite syenite, corundum syenite.		? Crystalline limestone in schistose terrane.
Mount Girnar, India.	Nephelite syenite, monchiquite.	Olivine gabbro, diorite.	?
Southern China.	Nephelite syenites.		? Paleozoic (Devonian) calcareous terrane "d'une immense étendue."
Jenisseisk (P. Tunguska), Siberia.	Leucite syenite porphyry.	Olivine-augite-plagioclase rock.	Silurian limestone.
"Ostsibirien" (Jenissiesk).	Teschenite.	Melaphyre.	Limestones and dolomite.

AUSTRALIA.

Warrumbungle Mountains, New South Wales.	Phonolite, trachyte, pseudoleucite phonolite, trachydolerite, comendite, melilite basalt (bearing corundum).		Calcareous shale of Triassic; Paleozoic limestones beneath the Triassic?

Table showing Field Associations of Alkaline and Subalkaline Eruptives—Continued.

Region.	*Alkaline eruptives.*	*Associated subalkaline eruptives.*	*Carbonate rocks cut by alkaline eruptives.*
Nandewar Mountains, New South Wales.	Akerite, nephelite syenite, bostonite, trachyte.	Basalt, rhyolite.	? Paleozoic limestones and calcareous sandstones, shales, etcetera ?
New South Wales province in general (eight districts).	List same as for Warrumbungle and Nandewar Mountains; also leucite basalt, etcetera.	Basalt, granites, dacite, andesites, etcetera.	Permo-Carboniferous, Devonian, and Silurian limestones and calcareous shales. Pre-Cambrian limestone ?
Queensland (five districts).	Monzonite, keratophyre, trachytes, comendite, etcetera.	Ditto.	? Palezoic limestones ?
ANTARCTICA.			
Track of the "Discovery" party; mainland, Ross Archipelago, etcetera.	Kenite, trachyte, leucitekenite, phonolite, trachydolerite, limburgite, camptonite, etcetera.	Basalt, granite, etcetera.	? Thick crystalline limestones of gneissic terrane ?
ISLANDS.			
Possession Island, Antarctic.	Phonolite.	Basalt.	?
Dunedin, New Zealand.	Foyaite, trachydolerite, teschenite, trachyte, kaiwekite, phonolite, tinguaites, leucitophyre, nephelite basanite, trachytes, melilite basanite.	Feldspar basalt, dolerite, diorite.	Tertiary limestone and calcareous sandstone. (Older limestones and marls ?)

Table showing Field Associations of Alkaline and Subalkaline Eruptives—Continued.

Region.	*Alkaline eruptives.*	*Associated subalkaline eruptives.*	*Carbonate rocks cut by alkaline eruptives.*
Tasmania, Port Cygnet, etcetera.	Nephelite syenites, augite syenite, essexite, jacupirangite nephelinite, tinguaite, nephelite, basalt, melilite-nephelite basalt, limburgite, etcetera.	Diabase.	Paleozoic limestones.
Timor.	Foyaite.	Diabase, andesite.	Tertiary and Carboniferous limestones.
Java.	Tephrite, leucite basalt, leucitite.	Feldspar basalt, andesite.	? Limestone in older terrane (Verbeek and Fennema).
Viti Archipelago.	Foyaite.	Basalt, gabbro, diabase, granite, etcetera.	? Crystalline limestone in island basement. Younger limestones?
Savaii, Samoa.	Trachydolerite.	Olivine basalt.	?
Tahiti.	Nephelite syenite, monzonite, tinguaite, monchiquite, nephelinitic gabbro.	Basalt, gabbro.	?
Hawaii.	Phonolitic trachyte.	Olivine basalt, augite andesite.	? Ancient coral reefs, oozes, etcetera.
Maui.	Melilite - nephelite basalt.	Ditto.	?
Oahu.	Nephelite basalt, melilite-nephelite basalt.	Ditto.	?

Table showing Field Associations of Alkaline and Subalkaline Eruptives—Continued.

Region.	*Alkaline eruptives.*	*Associated subalkaline eruptives.*	*Carbonate rocks cut by alkaline eruptives.*
Madagascar.	Nephelite syenite, nephelite basalt, phonolite, trachyte, limburgite, camptonite, melilite basalt, laurvikite, monzonite, augitite, essexite.	Diabase, feldspar basalt, gabbro.	Jurassic limestones and marls. (Older limestones?)
Trinidad, South Atlantic.	Phonolite, nephelinite, limburgite.		? Coral reefs?
Heard.	Nephelite basalt, limburgite.	Feldspar basalt.	?
Kerguelen.	Phonolite, trachyte, limburgite.	Feldspar basalt.	? (Roth found dolomite here.)
Nightingale.	Phonolite.	Andesite.	?
Fernando Noronha.	Phonolite.	Feldspar basalt.	?
Cabo Frio (Brazil).	Foyaite, pulaskite, essexite, tinguaite, monchiquite.		?
Saint Helena.	Phonolite.	Feldspar basalt, olivine basalt.	?
Ascension.	Alkaline trachyte.	Ditto.	?
São Thomé.	Phonolite, trachyte	Feldspar basalt, andesite.	?
Los Islands (Africa).	Nephelite syenite.		?

Table showing Field Associations of Alkaline and Subalkaline Eruptives—Continued.

Region.	*Alkaline eruptives.*	*Associated subalkaline eruptives.*	*Carbonate rocks cut by alkaline eruptives.*
Canary Islands.	Phonolite, trachydolerite, basanite, nephelinite, limburgite, tephrite, essexite, nephelite syenite, monzonite, camptonite, bostonite, gautëite, limburgite, nordmarkite, pulaskite, akerite.	Feldspar basalt.	? Mesozoic and Paleozoic limestones beneath volcanoes? Limestone on Fuerteventura. (Continuation of Atlas Mountains limestone formations?)
Cape Verde Islands.	Foyaite, syenite, phonolite, leucitite, tephrite, basanite, nephelinite, nephelite basalt, limburgite, etcetera.	Diabase, basalt, diorite, etcetera	? Limestones of Mayo, S. Thiago, and Praya islands?
Greenland.	Foyaite, sodalite syenite, lujaurite, etcetera.	Diorite, granite.	? (Pre-Cambrian limestones?)
Columbretes (Mediterranean).	Phonolite, trachyte.	Olivine basalt.	?
Monte Ferru, Sardinia.	Phonolite, trachydolerite, leucite basanite, leucite basalt.		Tertiary limestones and marls (older limestones?).
Pantelleria.	Phonolite, trachydolerite.	Feldspar basalt, olivine basalt of Ferdinandea Island (1831).	? (Tertiary and Mesozoic limestones?)
Lipari Islands.	Leucite basanite, trachydolerite, etcetera.	Basalt, liparite.	? (Tertiary and Mesozoic limestones?)

For 107 of the 155 districts tabulated the rule connecting alkaline eruptives and carbonate rocks is quite clear. In many of the remaining cases, including most of the oceanic islands, full information as to the nature of the formations invaded by the magmas could not be found in the literature or in geological maps. The phonolitic intrusives and lavas of the Cripple Creek district, Colorado, cut pre-Cambrian granites, and there is little probability that their magma could have made contact with any limestone overlying those granites. The alkaline rocks of Red Hill, New Hampshire, cut orthogneiss which seems to be similarly barren of carbonate beds, but it is possible that limestones occurred in the roof of the Red Hill stock; or it is possible that both the Red Hill and Cripple Creek granites traversed by the alkaline magmas had incorporated (stoped down) large masses of limestone during the earlier, batholithic intrusion, and that these limestones were cut by the foyaitic magmas. That this speculation is not entirely fantastic is shown by the fact that the deeper mine workings of the Cripple Creek district are seriously affected by abundant emanations of carbonic acid gas; that gas comes from below or from the volcanic rocks in which the levels are run and the shafts sunk; or, finally, it is possible that the Cripple Creek, Red Hill, and some other alkaline magmas have nowhere made contact with carbonate rocks, though those magmas were for some special reason unusually rich in juvenile carbon dioxide.

These exceptional cases suggest the hypothesis that it is the presence of carbon dioxide rather than of dissolved carbonate in subalkaline magma, which is the principal condition for the differentiation of fractions high in alkalies. The following discussion will, however, refer chiefly to the effect of the assimilation of limestone and dolomite, with their combined carbon dioxide, by subalkaline magma.

Effects of the Solution of Carbonates in subalkaline Magma

Needless to say, the experimental data are yet insufficient for a complete physico-chemical analysis of this subject. What follows is but a series of the more manifest suggestions or inferences derived from general studies of silicate melts and of the solid rocks. Incomplete as the deductions may be, they all point toward the one conclusion—that subalkaline magma must suffer such chemical modification by the assimilation of carbonates as will lead to fractions which are either abnormally rich in the alkalies or are so far desilicated as to yield, by crystallization, feldspathoids instead of feldspars. The various points will be very briefly stated, for it is the writer's purpose to draw to the main hypothesis the attention

of geologists and others who, by training, are better qualified to discuss the physico-chemical processes involved. A few illustrative points may be noted, with the commonest lava, basalt, taken as a type of the subalkaline magma.

1. Limestone or dolomite is a flux for basalt. The solution of a small proportion of either carbonate promotes fluidity. If there be any tendency toward the separation (by gravity) of leucocratic and melanocratic elements, this differentiation is directly aided by increased fluidity. Square Butte and Shonkin Sag prove very clearly that there is such tendency in magma (leucite basalt, cutting thick limestones) which, in chemical composition, differs relatively little from feldspar basalt.[4]

The facts concerning many other igneous bodies teach the same truth, namely, that gravitative differentiation, with concentration of alkalies in the upper part of magma chambers, is a normal process in those magmas which retain considerable fluidity near the crystallization temperatures of the femic and "cafemic" (calcium-iron-magnesium) components. This result is evidently brought about by fluxing.

2. The solution of limestone in basalt is accompanied by the dissociation of at least part of the carbonate. The lime binds several times its own weight of silica, with which iron oxides and magnesia may be also combined, forming pyroxene. The introduction of more of the ion, CaO, already present in the magmatic solution, promotes the precipitation of augite, anorthite, and other lime-bearing crystals or liquid phases.[5] An inoculation of the solution is evidently produced by the exotic carbonate.

3. The sinking of the femic and cafemic constituents (in solid or liquid phases) leaves the upper, residual part of the magma richer in alkalies than the original basalt. So far as the foreign lime has bound silica and carried it down in the sunken constituents, the residual magma is desilicated as compared with the original basalt. If the desilication is sufficient, nephelite forms instead of plagioclase. If augite is formed by the interaction of the foreign rock, a considerable desilication is possible, for the lime then binds about 2.5 times its own weight of silica. The formation and sinking of calcic, cafemic, and femic constituents leave the residual solution rich in alumina.

4. The carbon dioxide freed from the lime of the foreign rock must have a profoundly disturbing effect on the chemical equilibrium of the basalt. What that effect is can not be told until new, complete experi-

[4] L. V. Pirsson: Petrography and geology of the igneous rocks of the Highwood Mountains, Montana, Bulletin 237, U. S. Geological Survey, 1905.

[5] Similarly, if barium chloride is added to a saturated solution of barium sulphate, almost all of the barium sulphate is precipitated. See J. H. L. Vogt: Tschermak's Mineralogische Mitteilungen, vol. 27, 1908, p. 134.

ments have been made on such a solution. It appears possible that, in the absence of uncombined silica, the carbon dioxide would form compounds with the alkalies. These familiar fluxes would tend to rise toward the top of the magma chamber. A given amount of the acid would transfer a larger amount of either soda or potash. With falling temperature and at the pressures appropriate to the upper part of the chamber, the carbon dioxide would be slowly replaced by silica and expelled through the roof of the chamber. On the other hand, the reaction may be much more complicated than that suggested, and, in fact, it is likely that the alkalies often move upward in the form of aluminosilicate. The problem illustrates the darkness yet shrouding the operations of the "agents minéralisateurs."

That there is an actual transfer of one or both alkalies is shown in such examples as basanite, leucite basalt, and nephelinite.* The alkaline contents of these rocks can not be explained as features of magmas which are residual after the settling out of femic and cafemic constituents from normal basalt.

Without speculating further as to the nature of the physico-chemical changes, we may note that both acid and basic elements of dissolved carbonates cooperate in concentrating alkalies in the upper part of a column of basalt. A similar argument and conclusion may be derived for other subalkaline magmas.

Additional Evidences favoring the Hypothesis

Besides the facts of field association and the high probability of appropriate physico-chemical reactions, there are a number of important considerations favoring the general thesis of this paper.

Many special pyrogenetic minerals, more or less peculiar to the alkaline rocks, herewith find that explanation which is often so difficult on the supposition that these rocks have crystallized from primary magma. The list includes:

First. Minerals with carbon dioxide as an essential component: calcite and cancrinite of nephelite syenite, etcetera.

Second. Minerals showing desilication of normal subalkaline magmas: nephelite, leucite, muscovite (? in part ?), sodalite, haüynite, analcite, corundum, spinel.

Third. Minerals formed through the presence of excess lime: melilite, scapolite, wollastonite, garnet, titanite (in part), calcite, anorthoclase (in part ?), perovskite.

* See table of average compositions of these and other types in Proceedings American Academy of Arts and Sciences, vol. 45, 1910, pp. 228-229.

Fourth. Mineral derived from organic matter in limestone (?): graphite in some nephelite syenites.

In Clarke's "Data of Geochemistry" a large number of experiments on the origin of these minerals are described in abstract from the writings of many observers.[6] These artificial reproductions show instructive analogies to the processes which doubtless affect the crystallization of a limestone-basalt syntectic. Particular reference may be made to the syntheses of cancrinite, nephelite, leucite, analcite, haüynite, corundum, melilite, scapolite (meionite), wollastonite, garnet, titanite, and graphite.

The metamorphism of limestones and dolomites by intrusive masses involves chemical changes which are somewhat similar to those taking place in the syntectic of limestone and subalkaline magma. The production of garnet rock, epidote rock, diopside rock, or amphibolite in contact aureoles implies some desilication of the magma. It loses iron oxides as well. The alkalies are normally transferred into the contact rock to small degree, and are thus left concentrated in the magma.

A few relevant experiments may be noted. Limestone flux precipitates magnetite from furnace slag. Similarly, diopside and wollastonite molecules are, after the lapse of sufficient time and at moderate superheat, segregated in special abundance at the bottom of glass furnaces, the overlying layers of the melt being richer in the alkaline silicate. On the other hand, the writer is not acquainted with any case where the positive concentration of alkalies in a subalkaline magma through the action of limestone fluxing has been carefully studied in laboratory or commercial plant.

Possible Objections to the Hypothesis

At present this suggestion as to the origin of the alkaline rocks obviously suffers from incompleteness on the physico-chemical side. However, enough is already known to assure any future investigator that he will obtain valuable results on fashioning his experiments along the lines of the present hypothesis; the geological facts seem to show that those results will favor the general idea of limestone control, or at least carbon dioxide control, in the development of alkaline rock magmas.

The hypothesis as above outlined is a special case in the general syntectic-differentiation theory of igneous rocks and may prompt the objections which have been directed against the theory.[7] There are plenty of field examples showing that the magmatic heat of basalt is ample to fuse

[6] F. W. Clarke: Bulletin 330, U. S. Geological Survey, 1908.
[7] R. A. Daly: American Journal of Science, vol. 26, 1908, p. 49.

so refractory a rock as gneiss or granite. The temperature of the active Kilauean vent is at least 1200° centigrade. If the fusion or solution of gneiss takes place at any such temperature, we must believe that fluxing carbonate can enter into solution with the molten basalts of nature. It appears that any subalkaline magma would be similarly fluxed. A few rock types such as melilite basalt probably represent syntectics which have differentiated only slightly, but, in general, differentiation will be specially active in limestone syntectics. Typical hybrid rocks are, therefore, not to be expected in most districts. On the contrary, differentiates poor in lime are the result of the absorption of limestone by subalkaline magmas. Such a differentiate is found near the top of the magma chambers. The known structural relations of nephelite syenites and of phonolites are appropriate to this position of the extreme polar differentiate in intrusive mass or lava column. If magmatic stoping of limestone takes place, the ensuing assimilation is abyssal, and the actual syntectic solution or rock may never be accessible to direct observation. Finally, it must be remembered that most stock and batholith contacts have been established after molar-contact assimilation has become almost impossible in the already much cooled magma. The question of magmatic assimilation can never be so easily settled as by a mere inspection of main contacts or of xenolithic inclusions. To deny the efficiency of magmatic assimilation on such evidence is scarcely a scientific judgment.

A conceivable objection to the hypothesis is that limestones and other calcareous sediments are very generally distributed over the earth's surface, and accordingly the observed association of alkaline rocks and the sediments is accidental and without significance. A final reply to this objection would involve a full discussion of the field relations of the subalkaline rocks. This colossal task need not be undertaken, for a partial review of the subalkaline rock occurrences must make it clear to every one that very many, perhaps most, of these bodies have not contacted with limestone during eruption.

Again, the hypothesis must take account of a considerable number of cases where subalkaline rocks now make contact with masses of calcareous sediment and are not accompanied by rock types which are evidently alkaline by our definition of the term. This is true of many batholiths which have absorbed much silicious rock as well as limestone. The net result has been to give an acid syntectic and then quartzose or feldspathic differentiates at the batholithic roofs. On the other hand, the absorbed sediments are often so great in amount as to give syenite instead of granite. If the limestone is relatively abundant, the syenite may be of nordmarkitic, pulaskitic, or other alkaline type. In the rare

cases where limestone is extremely voluminous as compared with the acid rocks invaded, a granitic batholith may be locally desilicated and differentiated so as to produce nephelite syenites. Illustrations are seen in the great batholiths of eastern Ontario, as described by Adams, Barlow, Coleman, and others.[8] Many other bodies, smaller than batholiths, have no alkaline differentiates. Most of them were clearly too small to have assimilated any notable quantity of foreign rock, even of limestone. Some bodies have failed to assimilate because of their low temperatures. Where thermal and other conditions are necessarily so variable, *each case has evidently to be studied by itself* before its bearing on our general hypothesis is visible.

Alkaline Rocks not associated with calcareous Sediments

It would not be surprising if in future time it is demonstrated that some of the so-called alkaline rocks were evolved under conditions *essentially different* from those controlling the formation of such types as phonolite, nephelite syenite, theralite, etcetera. For example, many alkaline granites which cut granodiorite masses are most probably salic differentiates of the granodioritic magmas. In many of these cases the differentiation seems to be a result of the spontaneous splitting of the magmas rather than an effect of their absorption of foreign material. The splitting may have been assisted by the concentration of gases in part of the batholithic chamber, but those gases may *be juvenile and not "resurgent."*[9]

An analogous cause for the differentiation of phonolite has been suggested in the case of the Cripple Creek district. The alkaline masses of that region occur on the top of the great dome which, in Tertiary time, was upwarped to form the Front Range of Colorado. The development of such a dome must mean an extensive inflow of the plastic material on which the deformed granite rests. The disturbance might readily be conceived to lead to the concentration of juvenile gases, including carbon dioxide, beneath the domed granitic shell. A late Tertiary abyssal injection of basaltic magma would naturally carry much of this accumulated gas; the differentiation of this magma might give the latite-phonolite,

[8] F. D. Adams and A. E. Barlow: Transactions of the Royal Society of Canada, third series, vol. 2, section 4, 1909, p. 8. A. P. Coleman: Journal of Geology, vol. 7, 1899, p. 437.

[9] The writer uses "resurgent" as a technical term to designate those volatile substances which, as constituents of sedimentary rocks assimilated by magma, have been given off from the secondary, syntectic magma. Juvenile gases, on the other hand, are those emanating for the first time from the earth's interior. See American Journal of Science, vol. 26, 1908, p. 48.

phonolite, and nephelite syenite of Cripple Creek. The alkaline fractions of the differentiation were, on this view, segregated through the influence of the juvenile gas in the same manner as that postulated when the carbon dioxide of absorbed limestone segregates the alkaline elements in basalt. Similarly, the phonolites and allied types of many volcanic islands (Hawaii, Kerguelen, etcetera,) may owe their origin to juvenile carbon dioxide, but in no case is it possible to exclude the possibility that marine limestones underlie the respective volcanoes and furnished resurgent carbon dioxide to the magmas.

These speculations have little other value than that they show the inadvisability of trying to explain all alkaline rocks in the same way. However, most of the theoretical suggestions of this paper may be generalized as a plea for the recognition of magmatic gases, largely of resurgent origin, as powerful agents in the segregation of alkaline magmas from the subalkaline. The process represents a special case in the differentiating effects of the "fluides minéralisateurs." The writer is inclined to go further than Michel Lévy and other advocates of this theory and definitely to coordinate most of the alkaline rocks with syntectic magmas composed of subalkaline magmas and calcareous sediments.

General Conclusions

The results of this study belong to two different orders. In part they are clearly facts, restated or newly stated and independent of theory; in part the results are hypothetical, and the value of these depends on their finding position in a stable petrogenic theory.

Among the facts needing emphasis in a general treatment of the alkaline rocks are the following:

1. The alkaline rocks are seldom, if ever, found without associated subalkaline rocks. Of the latter those derived from basaltic or gabbroid magma are the types most constantly associated.

2. Either as individual masses or in total volume the visible alkaline bodies are incomparably less important than the subalkaline bodies. The ratio of the total volumes is in the order of magnitude of one to one hundred. This ratio applies very nearly to the Atlantic basin as well as to the Pacific basin. As the Pacific basin is being explored, more and more alkaline masses are discovered. The division of igneous rocks into Atlantic and Pacific branches, as advocated by Becke, Harker, Prior, and others, is not warranted by the facts of distribution, and is not so safely made as the division into alkaline and subalkaline branches.

3. Many of the so-called subalkaline rocks are richer in soda and potash than many of the so-called alkaline rocks. There is no a priori reason why, under certain conditions, subalkaline magmas should not yield typical alkaline rocks by differentiation. For example, a small body of phonolite could be differentiated from a large body of basaltic magma without giving a femic pole strange to petrography.

4. Many alkaline igneous types are chemically and mineralogically transitional into subalkaline types.

5. At least two-thirds of the alkaline rock districts of the world contain thick masses of limestones, dolomites, or other calcareous sediments which have been cut by the alkaline eruptives. For the remaining cases, except, possibly, the Cripple Creek district, information is lacking as to the precise nature of the intruded formations.

6. Many of the minerals special to the alkaline rocks are among those known to form in silicate melts or magmas which have dissolved limestone or other carbonate. The list of such minerals includes primary cancrinite, primary calcite, haüynite, melilite, scapolite, wollastonite, garnets, titanite, graphite, analcite, perovskite, etcetera.

7. The most typical alkaline rocks are so low in silica that feldspathoids, instead of feldspars, crystallize out.

The theoretical suggestions derived from these facts may be likewise summarized:

1. The alkaline rocks have been derived from the steadily associated subalkaline magmas. Phonolites, many nephelite syenites, nephelite basalts, nephelinites, leucite basalts, leucitites, melilite basalts, tephrites, basanites, trachydolerites, theralites, etcetera, appear to be genetically connected with common feldspar basalt. In some cases, like the nephelite syenites of eastern Ontario, typical alkaline bodies are syngenetic with granites, which themselves, in probably all instances, cut calcareous sediments.

2. The segregation of the alkalies and the observed desilication of the subalkaline magmas are largely explained by the assimilation of the natural carbonates. It is conceived that the whole of the carbonate may take part in the appropriate chemical reactions; or that sometimes the subalkaline magma is affected only by the carbon dioxide which is driven off from invaded limestone by magmatic heat into the volcanic vent or other magmatic chamber. Various suggestions are offered as to the nature of the reactions, but they are all strictly tentative and need checking by physico-chemical experiments. Evidence is given for the view that, independently of the other reactions, one or both of the principal alkalies are caused to migrate positively, giving such types as tephrites and leucite

basalts from the differentiated syntectic of carbonate with feldspar basalt. It is conceivable that dolomite and pure limestone have different effects in the reactions, the one concentrating more soda, the other more potash.

3. The amount of natural carbonate required to develop an alkaline differentiate is seen to be small, as compared with a given volume of subalkaline magma.

4. The minerals peculiar to, or characteristic of, alkaline rocks find explanation on the hypothesis proposed.

5. Many alkaline granites and feldspar syenites have no apparent genetic connection with limestones, and to some of these igneous types the carbonate-syntectic hypothesis is not extended. They are often, however, differentiates from subalkaline magmas like granodiorite, etcetera. Many of the syenites cut thick series of sediments other than limestone. The solution of these other sediments with subalkaline magma must upset its chemical equilibrium. Whether alkaline differentiates would result is a question the discussion of which is fraught with yet greater physico-chemical difficulties than that above outlined. No attempt is made to answer this question, which involves more or less special conditions for each of the different localities. Some of the alkaline feldspar syenites cut both silicious and calcareous sediments. Their origin is made clearer by an experiment by Schweig, who showed that if molten nephelite syenite is saturated with silica, the resulting syntectic is approximately the average pulaskite.[10]

The possibility is recognized that juvenile as well as "resurgent" carbon dioxide (with other gases) may, in some cases, have accumulated in subalkaline magmas, which have differentiated, giving alkaline poles similar to those derived from syntectics with limestone. For the Cripple Creek phonolitic rocks a special mechanism for the accumulation of juvenile gases is suggested, but it is possible that the abundant carbon dioxide of the mine workings there emanates from limestone stoped down by the pre-Cambrian granites. Analogous difficulties are found in applying the general hypothesis to a few other districts, including Red Hill, New Hampshire; the Great Rift Valley of Africa; some of the Brazilian occurrences, etcetera. For these cases the petrologist needs more data from the field geologist, especially as to the nature of the formations making roofs and walls of the eruptive masses. Many papers, lacking in this fundamental statement, are almost useless to the student of petrogeny.

6. Generalizing, the alkaline rocks may be regarded as differentiates of syntectics. In most instances the foreign matter dissolved in the sub-

[10] M. Schweig: Neues Jahrbuch für Mineralogie, etc. Beilage Band 17, 1903, p. 517.

alkaline magma is solid rock, usually carbonate. In others, the foreign matter may be gas, usually carbon dioxide, which has a juvenile origin. This paper has specially discussed the first group of cases. Many of the leading petrologists refuse to credit the syntectic idea with having any general value in the petrogenic problem, but their scepticism is scarcely justified by the facts of the field. In any case it is idle to refuse assent to the proposition that magma with the known volcanic temperatures is capable of assimilating limestones and dolomites.

His own field experience has led the writer to a position much like that held by Loewinson-Lessing, who states that "bisweilen genügt ein Einschmelzen einer unbedeutenden Menge irgend eines fremden Stoffes, der im Magma oder in einem Theil desselben wenig löslich ist, um einen Anstoss zur Spaltung in mehr oder weniger grossem Maasstabe zu geben."[11] The present writer would extend the idea so that large-scale differentiation is regarded as often induced by assimilation of foreign rock-matter which, as such, is entirely miscible with the original magma. The true, compound solutions so produced differentiate according to reactions other than those affecting the pure, original magma. Thus, for example, augite andesite is a differentiate of basalt; nephelinite is one of the differentiates from a basalt-limestone syntectic.

The hypothesis is also in line with the older views, since it offers a special instance of the action of the "fluides minéralisateurs," which have been so long emphasized by the French workers in petrogenic theory.

A complete genetic study should discuss the many alkaline types individually. This is not attempted, for the detail of their differentiation is not essential to the main thesis of this paper. An inspection of the literature of the tabulated occurrences shows that magmatic splitting has often taken place in successive stages. That gravity may be in control throughout is suggested by the conditions at Square Butte and Shonkin Sag, Montana. In each of these localities alkaline syenite overlies shonkinite, and both types have been derived from a magma with the composition of leucite basalt. The method of the differentiation is like that in the more acid syntectics of the Moyie, Pigeon Point, and Sudbury sheets; and the general importance of gravitation (with separation of salic and femic constituents) in magmatic splitting is attested by a multitude of other facts of the field.[12] In other words, the alkaline magmas seem to obey the same general laws as those affecting the more voluminous subalkaline

[11] F. Loewinson-Lessing: Compte Rendu de la VII^me^ session, Congrès géologique international, Saint Petersburg, 1897 (1899), p. 380. See also p. 358.

[12] See American Journal of Science, vol. 20, 1905, p. 185, and Festschrift zum siebzigsten Geburtstage von Harry Rosenbusch, Stuttgart, 1906, p. 203.

magmas. The chemical contrasts between the two groups are explained by the assimilation or syntectic theory, as that theory also recognizes the principal importance of magmatic differentiation.

The writer is not able to make Jensen's hypothesis as to the origin of alkaline rocks agree with the known facts of rock distribution and with chemical relationships.[13] The general association of alkaline rocks with sediments is here explained in a quite different way. Jensen's conclusion that most of the alkaline rock eruptions are of late geological dates may possibly bear on the limestone-syntectic hypothesis, since it has taken much of geological time to accumulate the thick masses of calcareous sediments which are cut by alkaline bodies.

Finally, the general thesis explains the localization of rock types occurring in the alkaline "petrographic provinces." The Norwegian, Bohemian, Italian, Monteregian, Montanian, Texan, Australian, Tasmanian, and other provinces are alkaline with respect to igneous types and calcareous with respect to their sediments; and no one of these provinces lacks subalkaline eruptives. Yet explanation is not proof; this must await the discovery of many new facts and the judgment of physical chemists cooperating with field geologists. The alkaline group of igneous rocks seems to offer a specially valuable test of any petrogenic theory.

[13] H. J. Jensen: Proceedings of the Linnean Society of New South Wales, vol. 33, 1908, p. 491.

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
VOL. 21, PP. 119-140, PL. 2 MARCH 31, 1910

EVIDENCE THAT THE FOSSILIFEROUS GRAVEL AND SAND BEDS OF IOWA AND NEBRASKA ARE AFTONIAN[1]

BY B. SHIMEK

(Presented by title before the Society December 30, 1909)

CONTENTS

	Page
Previous discussions	120
Importance of the Aftonian mammalian fauna	120
Correlation with other deposits	120
Evidence of climatic conditions	120
Significance of the Aftonian molluscan fauna	121
The Aftonian mollusks	121
Comparison with modern mollusks	122
Evidence of climatic and surface conditions	123
Importance of exact determination of Aftonian horizon	123
Evidence that beds are Aftonian	124
General characteristics of the Aftonian	124
Composition and structure	124
Distribution of fossils	125
Stratigraphic relation, Pleistocene section	125
Detailed description of fossiliferous sections	126
Order of treatment	126
1. Akron section	126
2. Searles section	127
3. Anderson section	128
4. New Woodward section	128
5. Weniger pit	129
6. Elliott pit	129
7. Ordway pit	130
8. Ordway well	131
9. Griffin well	131
10. Wilkenson well	132
11. Hawthorn pit	132
12. McCleary pit	132
13. County line exposure	132
14. Peyton pit	133
15. Wallace pit	134
16. Robinson pit	134

[1] Manuscript received by the Secretary of the Society December 30, 1909.

Page
17. Cox pit 135
18. Peckenpaugh sections 136
19. Denison pit 137
20. Offerman pit 138
21. Gladwin section 138
22. Mad Creek section 139
Are the fossils Aftonian? 139
Conclusions 140

Previous Discussions

About a year ago the writer announced[2] the discovery in western Iowa of Aftonian sands and gravels containing mammalian and molluscan remains.

Subsequently Calvin included a brief discussion of the same deposits in his presidential address,[3] and in the same volume[4] described the mammalian fossils in detail.

In none of these papers was an effort made to present the full evidence on the basis of which the reference to the Aftonian was made, and the correctness of this reference has been questioned recently in private correspondence.

At the December, 1908, meeting of the Geological Society of America the writer presented a paper,[5] the publication of which was somewhat delayed,[6] in which this question was discussed to some extent, but no special emphasis was placed upon the fossiliferous portions of the formation.

Importance of the Aftonian mammalian Fauna

correlation with other deposits

The discovery of a distinct Aftonian fauna is not only of interest and value in itself, but it has an important bearing on a number of interesting questions.

Thus it may make possible the closer correlation of formations like the *Equus* beds, Sheridan beds, etcetera, which contain practically the same mammalian fauna.

evidence of climatic conditions

Moreover, the presence of this fauna makes possible for the first time

[2] Science, vol. xxviii, 1908, p. 923.
[3] Bull. Geological Society of America, vol. 20, 1909, pp. 137-139.
[4] Ibid., pp. 341-356.
[5] Read by title.
[6] Bull. Geological Society of America, vol. 20, 1909.

the more accurate determination of the climatic conditions which prevailed during the Aftonian interglacial period.

Some light is thrown upon these conditions by the presence of a mammalian fauna made up of large herbivorous animals, which probably required great quantities of plant food and could live only in a climate supporting abundant terrestrial plant life. While all these species of mammals are now extinct and it is not entirely safe to draw conclusions concerning habits from mere relationship, it seems reasonable to conclude that the climate was sufficiently mild to support the necessary plants.

Significance of the Aftonian molluscan Fauna

THE AFTONIAN MOLLUSKS

The molluscan fauna, though apparently insignificant when compared with the giant mammals which were discussed by Calvin, furnishes evidence concerning climatic conditions which is really much more conclusive, for the mollusks of the Aftonian are identical with those which inhabit Iowa and adjacent territory today, and the habits of all these species are definitely known.

But the very fact that these species exist today introduces an element of possible error which makes the exact determination of the horizon from which they come very necessary; for similar or identical series of shells may be collected both in our present waters and in very modern alluvial deposits, and these species probably invaded the region of Iowa during every interglacial period of Pleistocene time.

The following species of mollusks have been collected by the writer from the Aftonian beds in Iowa:

Aquatic Species

Unio metanever Raf.
Unio anodontoides Lea (?).
**Sphærium sulcatum* (Lam.) Pr.
**Pisidium* ——, probably 2 species.
**Amnicola* ——.
**Bythinella obtusa* (Lea) St.
**Valvata tricarinata* Say.
Valvata bicarinata Lea.
Ancylus rivularis Say.
Lymnæa reflexa Say.
**Lymnæa caperata* Say.
**Lymnæa humilis* Say.
**Physa* ——.
**Planorbis bicarinatus* Say.
**Planorbis parvus* Say.
**Planorbis dilatatus* Gld.

Terrestrial Species

Polygyra —— (fragment).
Pyramidula alternata (Say) Pils.
Pyramidula striatella (Anth.) Pils.
**Vallonia gracilicosta* Reinh.
**Vitrea hammonis* (Ström.) Pils.
Zonitoides arboreus (Say) Pils.
Bifidaria armifera (Say) Sterki.
Succinea ovalis Say (=*obliqua* Say).
**Succinea avara* Say.
Succinea retusa Lea.

In number of individuals the aquatic species predominate, the land shells being represented by but few specimens, which were evidently washed from near-by land surfaces.

These land species are all living in Iowa today, and their presence in the Aftonian is especially suggestive, since land shells suffer much more from climatic changes than do the aquatic species. Their presence proves the proximity of plant-covered land areas similar to those which now prevail in the region under discussion, and a climate not materially different from that which is found in Iowa today, at least so far as temperature is concerned.

COMPARISON WITH MODERN MOLLUSKS

In order that this similarity of Aftonian and modern molluscan faunas may be more fully appreciated, a comparison is here made between the fossils of the foregoing list and a series of shells dredged in Miller Bay, West Lake Okoboji, Iowa,[7] during August, 1908.

This bay forms a regular rounded indentation in the west shore of the lake. The dredging was done in shallow water, 4 to 8 feet in depth, near the head of the bay, just opposite the Iowa Lakeside Laboratory.

All the species in the foregoing list which are marked with an asterisk were also dredged from Miller Bay. Where only generic names are given, the Aftonian specimens are more or less imperfect, but apparently identical with species collected in the bay.

Unio anodontoides Lea (= *Lampsilis anodontoides* (Lea) Baker) and *Unio metanevrus* Raf. (= *Quadrula metanevra* (Raf.) Simp.) of the Aftonian seem to find substitutes in *Unio luteola* Lam. (= *Lampsilis luteolus* (Lam.) Baker) and *Anodonta* —— of the bay; *Valvata bicarinata* is found living in other parts of Iowa today; *Ancylus rivularis* is now common in the Des Moines River, less than 20 miles away, and *Lymnæa reflexa* is common in ponds in the vicinity of the lake and on other parts of the lake shore.

The bay also yielded 4 additional species of *Planorbis*, 2 of *Lymnæa* and 1 of *Bulinus*, all these aquatic and evidently living in the bay or in ponds communicating with it. The similarity of the aquatic fauna of the bay to the aquatic fauna of the Aftonian is striking. It is a fauna belonging to the larger streams and lakes, and is unlike the terrestrial fauna with its occasional small-pond pulmonates which characterizes the loess.

It will also be noticed that three of the terrestrial species occurring in the Aftonian were also dredged from the bay. Two specimens of *Succinea*

[7] Lake Okoboji is in northwestern Iowa, and the terrestrial molluscan fauna of its vicinity is practically the same as that of the region of the Aftonian exposures herein discussed.

avara and one each of *Vitrea* and *Vallonia gracilicosta* were secured in this way, together with one specimen of *Vallonia parvula* Sterki, a species not known from the Aftonian.

It is important to note the small number of terrestrial shells which find their way to the bottom of the bay, especially since terrestrial species are abundant in the groves bordering the bay, and great numbers of them are carried out on the lake by freshets to be thrown ashore again. This was well illustrated during the past summer, when great numbers of shells, largely terrestrial species, were thrown out on the north shore of Miller Bay. This bay is bordered by native forest on the west and south shores, and in these groves dwell more than 25 species of terrestrial mollusks, some of them in large numbers. The dead shells of these species, often perfectly fresh, are washed into the bay, and are driven to the north shore by the prevailing southerly or southwesterly winds, where they are literally massed in thousands on the flat beach,[8] together with aquatic species from the bay itself. Yet notwithstanding the great number and variety of forms[9] which are so carried across the bay, but few find their way to the bottom, as was shown by dredging.

EVIDENCE OF CLIMATIC AND SURFACE CONDITIONS

If now we apply approximately the same ratio to the terrestrial mollusks which are found in the Aftonian, we will find the terrestrial species even more abundant, and the climatic and surface conditions which made their existence possible much more general and widespread than might appear possible from the study of the extent of the Aftonian deposits themselves; for, with the exception of these few land shells, the evidence furnished by the Aftonian points to great floods, as the deposit was evidently largely formed by strong currents; yet the presence of these land shells (together with the presence of large terrestrial mammals) is sufficient to show that extensive land areas did exist.

IMPORTANCE OF EXACT DETERMINATION OF AFTONIAN HORIZON

In view of the foregoing considerations, it is important that, so far as possible, all doubt concerning the stratigraphic position of the beds which

[8] No forest suitable as a habitat for these species occurs on the slopes adjacent to the north shore of the bay, and the only possible source of these shells is on the opposite, or southerly, side of the bay.

[9] In the drift material on the north shore of the bay the writer found the following aquatic forms: 1 species of *Pisidium*, 1 *Amnicola*, 1 *Valvata*, 5 *Planorbis*, 1 *Segmentina*, 4 *Lymnæa*, and 1 *Bulinus*. Mingled with them in greater numbers were the following terrestrial forms: 1 species of *Carychium*, 1 *Euconulus*, 2 *Zonitoides*, 1 *Vitrea*, 1 *Pyramidula*, 1 *Helicodiscus*, 1 *Punctum*, 1 *Strobilops*, 5 *Bifidaria*, 3 *Vertigo*, 1 *Pupoides*, and 1 *Cochlicopa*. Hundreds of specimens of several of these species were collected.

yield fossils of such interest be set at rest. For that reason the writer presents here a detailed account of the evidence of stratigraphic position furnished by each of the twenty fossiliferous exposures which have been studied in Iowa and Nebraska, and also includes a list of the fossils obtained from each, in order that the distribution of these fossils may be more clearly set forth.[10]

Evidence that Beds are Aftonian

General characteristics of the Aftonian

While specific attention is here given to the exposures of fossiliferous Aftonian, it should be borne in mind that there are many more exposures in the same region which have yielded no fossils, but which possess Aftonian characteristics to a greater or lesser extent. Not every exposure presents equally conclusive evidence, and some of the exposures would probably be unintelligible but for the light which comes from the study of the entire series.

Whatsoever may be the variation in this respect, it seems to be restricted within definite limits, for there are certain characteristics which prevail to such an extent that they may be regarded as collectively determining typical Aftonian, and while not all of them are present in every section, yet in the great majority of cases they are sufficiently well developed to make the identification entirely satisfactory.

Composition and structure

The composition and structure of the Aftonian beds, while somewhat variable, are sufficiently constant to assist materially in the identification of this formation. In the western part of Iowa and in eastern Nebraska they consist of gravel, sand, and fine silt, variously cross-bedded and interstratified. Usually each of these types of material appears distinct in a well defined wedge or stratum, and this segregation evidently represents local variation in the force of the currents. Sometimes only one or two of them make up the deposit, but more frequently all three types will be found in the same exposure, though varying very much in relative amount. Sometimes they are in part blended or mixed. Occasionally, especially where disturbed by the overlying Kansan, the Aftonian contains masses of Nebraskan or Kansan till. Very large boulders, usually granite or Sioux quartzite, sometimes occur in the sandy or gravelly parts.

[10] The mammalia mentioned throughout this paper were identified by Professor Calvin, the mollusks by the writer. The collections and the stratigraphic studies in the field were made chiefly by the writer for the Iowa Geological Survey.

The gravels vary in coarseness and composition, but the pebbles are commonly water-worn and frequently stained with iron to a deep rusty red. The sands are sometimes similarly stained, but vary to a pure white.

Both sands and gravels almost universally show black streaks, bands, and cloudings of MnO_2.[11]

Very soft, small, white nodules of $CaCO_3$ are also usually present in the sandy and gravelly parts.

The silt is usually yellowish, bluish, or nearly white and appears in thick strata, or more frequently in smaller plates and layers. It commonly shows lamination, and sometimes it is more or less mingled with sand.

In some parts of Iowa peat beds also occur, but they are practically absent from the western beds.

DISTRIBUTION OF FOSSILS

Much of this western Aftonian is fossiliferous. Twenty fossiliferous exposures have been carefully studied. Of these 1 is in eastern Nebraska, 18 in western Iowa, and 1 in eastern Iowa. Non-fossiliferous exposures were studied in much greater numbers in both states.

Of the twenty fossiliferous exposures, eight yielded mammals only, seven yielded mollusks only, and five contained both mammals and mollusks.

STRATIGRAPHIC RELATION, PLEISTOCENE SECTION

These fossiliferous beds lie unconformably between the Nebraskan (pre-Kansan) drift below and the Kansan above, and are interglacial and Aftonian.

This was first clearly shown to the writer in the county line exposure in the northern part of Harrison County, Iowa, where both tills are present, though he had in the Cox pit previously determined that they are below the Kansan.

Both tills are not always present, but the Pleistocene members which are present always maintain a consistent relative position, excepting in those limited local cases where the Kansan caused a little confusion by plowing up the Aftonian and Nebraskan.

In this connection a section of the Pleistocene of western Iowa may be of interest. The Pleistocene rests on the older rocks, which vary with locality, but in western Iowa are usually Missourian or Cretaceous.

Passing upward, a complete section will reveal the following:

[11] The presence of so much MnO_2 also indicates the occurrence at one time of large quantities of organic matter.

7. A yellow loess, light both in color and texture, probably post-Wisconsin, found only near the Missouri Valley, and blending more or less with (6).

6. A yellow, rather heavy loess, probably post-Iowan, blending with (7) and sharply separated from (5).

5. A bluish gray, compact post-Kansan loess, very variable in thickness.

4. The Loveland—a heavy joint clay, usually reddish, evidently belonging to the melting period of the Kansan, reaching at least 40 feet in thickness.

3. The Kansan drift, very variable in thickness.

2. The Aftonian gravel, sand, and silt, up to 40 feet in thickness.

1. The Nebraskan drift (pre-Kansan), which varies up to at least 40 feet in thickness, but the greater part of this buried under other deposits.

The total thickness of 5, 6, and 7 does not exceed 35 feet on the west side of the Missouri and rarely reaches 90 feet on the Iowa side.

DETAILED DESCRIPTION OF FOSSILIFEROUS SECTIONS

Order of treatment.—For convenience the sections are taken up in geographical order and are numbered consecutively, the general order being from north to south.

1. *Akron section.*—This was made in sinking a well on the Severin Jensen farm, in the northwest quarter of section 33, township 93 north, range xlviii west, about 2 miles east of Akron, Iowa.

The well is located on a gentle slope of one of the swells or ridges by which the typical rolling Kansan of this region gradually drops down to the valley of Beaver Creek a half mile north. The Kansan is here covered with loess, which is more or less fossiliferous, as at the quarter-section corner on the north line of section 32 and in the cellar of the Searles house mentioned below.

Mr. Jensen reports his well as 24 feet deep and reaching down to a "hard-pan" (probably Nebraskan drift). A somewhat deeper boring brought up "little pieces of slate" (probably Cretaceous shale).

Resting on this hard-pan are 7 or 8 feet of sand and gravel. At a depth of about 20 feet a bed of very ferruginous sand was encountered, and in this were found the bones and teeth of *Mammut mirificum*.

Above the sand and gravel (Aftonian) there is a bed of hard clay mixed with a little sand and gravel. A part of this was dark in color. This is evidently Kansan drift with Loveland joint clay.

The topmost layer is a softer yellow clay, evidently loess.

The owner had made several attempts to sink wells within a few rods of the present well. In one of these he found stratified water-bearing sand at a depth of 12 feet. In another near by he reached a "black hard-pan" (evidently Nebraskan), with a little sand and gravel (seemingly Aftonian) resting on it.

The following fossils were obtained from the Jensen well:

212.[12] *Mammut mirificum*, 2 molars (see Bulletin of the Geological Society of America, volume 20, plate 27).
216. Cranial bones of the same species.
217. Fragments of tusk of same species.
221. Homologue of the first and second phalanges of sloth.
Unidentified fragments of bone.

2. *Searles section.*—This is also a well section, reinforced by an excavation for a cellar near by. It is located a quarter of a mile west of section (1) and at a point somewhat lower.

The section as reported by Mr. Searles is as follows:

Dark brown surface soil, 3 to 4 feet.
Yellow clay, 12 to 13 feet.
Blue joint clay with boulders, 1 to 2 feet.
Sand, 2 feet.
Gravel, about 6 feet.
Shale, about 30 feet penetrated.

The yellow clay is probably loess and Loveland joint clay, these two usually being confused by well-diggers; the blue joint clay is evidently Kansan drift; the sand and gravel belong to the Aftonian, and the shale is Cretaceous.

The cellar, which is east of the well and a little lower, showed 4 to 5 feet of loess resting unconformably directly on a layer of gravel 1 to 2 feet in thickness, and this rested on fine sand. The sand and gravel are evidently Aftonian, the former containing fragments of shells of *Sphærium*, probably *S. sulcatum*.

The conclusions concerning the identity of the several strata in sections (1) and (2) are further strengthened by the fact that other sections in this region show a corresponding arrangement. The best of these sections, so far as the writer observed, is that in the first cut along the Chicago, Milwaukee and Saint Paul Railway 2 miles north of Chatsworth and about 8 miles north of the Jensen well.

Here about 18 feet of loess rest on a mass of Loveland and typical Kansan drift which is separated from the underlying dark Cretaceous shale by a distinct stratum of Aftonian sand and gravel. The Kansan and Aftonian are unconformable and are separated by a strongly oxidized ferruginous band.

[12] The numbers preceding the names of mammals in the lists included in this paper are Museum numbers, the specimens being deposited in the Geological Museum of the State University of Iowa.

3. *Anderson section.*—This is in a sand pit located in the southeast quarter of the northwest quarter of section 13, township 89 north, range xlviii west, north of North Riverside, Sioux City, Iowa.

The section shows the following members:

Loess, 8 to 12 feet.
The Loveland, an irregular mass of reddish joint clay.
Kansan typical bluish till, 6 to 8 feet.
Fine laminated bluish or yellowish silt, evidently Aftonian, 5 to 8 feet.
Aftonian sand, cross-bedded with streaks of MnO_2 and iron, and containing mammalian fossils, 22 to 30 feet.

Mr. Anderson reports larger boulders and gravel under the sand resting on rock.

The following fossils were collected in the Aftonian sand and gravel:

174. *Megalonyx* ——, ungual phalanx.
175. *Megalonyx* (?) ——, patella.
176. A canine tooth, not identified.
178–181. *Equus complicatus*, various teeth.
Various fragments of bones and teeth, not identified.

4. *New Woodward section.*—This is a new sand pit located in the southwest quarter of section 9, township 85 north, range xliv west, about 2 miles southwest of Rodney, Iowa. This exposure shows about 3 feet of fine, white, cross-bedded sand containing shells of mollusks, and above it an irregular mass of sand and gravel about 8 feet deep.

The material lying above the sand is not clearly defined, on account of slumping, but it is mixed drift and gravel, such as is common in this region, where the Kansan plowed into the upper part of the Aftonian.

The sand contains silt balls or pellets, such as are common in the Aftonian, and in all respects the structure and composition of the beds are typical. Moreover, several sections in the vicinity show the unmistakable presence of the Aftonian—one, located in Woodwards Glen, in the southwest quarter of section 17, showing a distinct layer of Nebraskan drift[13] immediately below the Aftonian.

The following mollusks were collected in the white sand in section (4):

Pisidium ——.
Sphærium ——, probably *S. sulcatum*, fragments.
Lymnæa ——, probably *L. humilis*, broken.

[13] The pre-Kansan, or sub-Aftonian drift, was named *Nebraskan* in Science, n. s., vol. xxxi, pp. 75-76, January 14, 1910. The name also appears in the Bulletin of the Geological Society of America, vol. 20, p. 408, dated December, 1909, but not distributed until after the publication in Science.

FIGURE 1.—WENIGER PIT

The irregular white line is the calcareous nodular band separating the Kansan drift from the Aftonian below

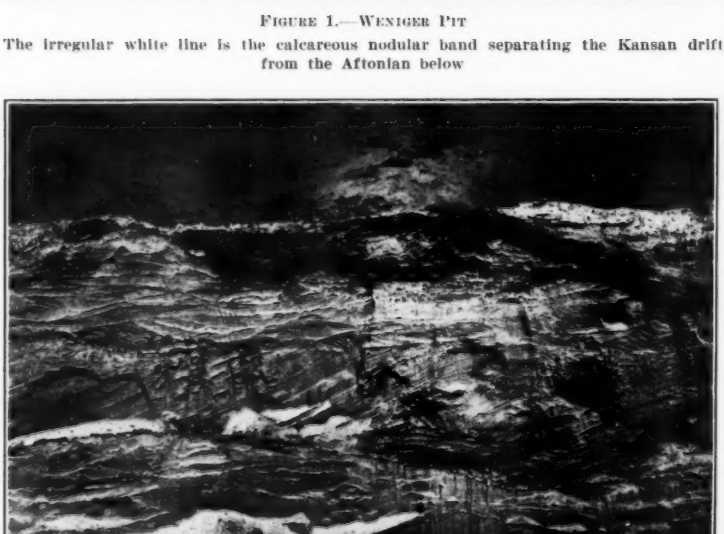

FIGURE 2.—PART OF THE ELLIOTT SECTION

Darker Kansan separated from cross-bedded Aftonian by sharp, somewhat oxidized line

5. *Weniger pit.*—This is a sand pit located in the east half of section 18, township 84 north, range xliv west, in Monona County, Iowa, in the bluffs facing the Missouri Valley. It shows 8 feet of sand and gravel on which typical Kansan drift, 2 to 4 feet thick, rests unconformably. The two deposits are separated by a distinct oxidized band and by a layer of calcareous nodular plates (see plate 2, figure 1).

The Aftonian here rises to about 40 feet above the Missouri bottoms, the average altitude of these beds in this territory.

Fragments of shells, probably *Sphærium*, were found in the upper, finer sand.

6. *Elliott pit.*—This is a sand pit located in the northeastern part of Turin, Iowa. The sand and gravel in this pit are typically Aftonian in the cross-bedding, streaking with iron and MnO_2, the presence of silt and drift nodules or pellets and white, soft, calcareous nodules, the occurrence of mollusks in the sand and mammalian remains in the gravel.

Moreover, the position of these beds removes all doubt as to their identity. Superintendent W. E. Babcock, of the cement tile factory operating this pit, reports that in boring in the pit they encountered, below the sand and gravel, a layer of "dark clay which was like rubber," into which they penetrated about 4 feet. They found it putty-like, tough, very hard to work, and containing occasional boulders. This is evidently Nebraskan drift, which is also well exposed in the same valley at Castana.

The Aftonian was exposed to a depth of about 12 feet. In the greater part of the exposure the fine sand lies above the gravel, though there is some interbedding, but near the south end a layer of coarse, ferruginous gravel rests on the sand.

The bones and teeth were found in gravel at a depth of 10 to 12 feet below the top of the Aftonian.

A distinct band of bluish or reddish laminated silt was found above the sand and gravel. It is about 2 feet thick, and evidently represents a slack-water deposit of the Aftonian. It grades downward into fine sand.

The superimposed formations, the Kansan drift, the Loveland, and the loess, are well developed, and the entire section is typical. The sharp contact line between the Kansan and Aftonian is shown in plate 2, figure 2.

The following vertebrate fossils were collected:

8. *Elephas* or *Mammut*, a cervical vertebra (see ibid., plate 25, figure 8).
161. Part of rib of proboscidian.
166. *Mammut americanum*, sixth molar.
187. *Camelus* ——, first phalanx.

122, 136. *Equus scotti*, superior molars.
227. *Equus scotti*, lower molar.
184. *Equus complicatus*, premolar.
229. Incisor of horse (?).
Miscellaneous bones and teeth of Equus: 4 cannon bones (169); phalanges (171-172, 195); a tooth (199), and fragments of teeth (228).
232. *Equus* ——, left radius (proximal end).
197. Jaw of ruminant, fragment.
230. Premolar of animal related to camel.
231. Foot bones of camel (2).
Various unidentified bones, mostly fragmentary.
Vertebra of a fish. Found in fine sand.

Mollusks

Unio anodontoides Lea (?).
Unio ——, fragments of a heavier species.
Sphærium sulcatum.
Pisidium ——.[14]
Amnicola ——.
Valvata tricarinata.
Valvata bicarinata.
Ancylus rivularis.
Lymnæa caperata.
Planorbis parvus.
Segmentina armigera.
Pyramidula alternata.
Pyramidula striatella.
Vallonia gracilicosta.
Vitrea hammonis.
Zonitoides arboreus.
Bifidaria armifera.
Succinea ovalis.
Fragments of 2 or 3 other species.

7. *Ordway pit.*—This is located in the bluff on the southwest side of the Maple River, opposite Castana, Iowa, in the southeast quarter of section 13, township 84 north, range xliv west.

The Aftonian here rises about 40 feet above the Maple bottoms. The section shows the following members present:

Loess, abundant on the ridge above the section.
Loveland, 5 to 6 feet.
Kansan drift, 6 to 18 feet.
Aftonian: fine, cross-bedded, with interstratified silt and other characteristics of typical Aftonian, 5 to 8 feet.
Aftonian ferruginous gravel, in part forming conglomerate plates, 3 to 4 feet.

Both this and the following section are on a Kansan sloping bench with no overlying loess. The loess begins higher up on the slope, and the ridge is capped with a thick deposit of it.

In the northern part of the same pit a layer of gravel 3 feet in thickness lies under the sand, and contained a stratum of mussel shells (mostly

[14] The species of *Pisidium* has not been determined, the recent revision of the genus making this more difficult, but it seems to be identical with the most common species now living in the northwestern part of the state.

heavy-shelled *Unio*) in which the shells were closely massed. They were very fragile and could not be taken out entire. With them were shells of *Sphærium sulcatum* and a shell of *Ancylus rivularis*. Several large boulders rested on this gravel layer.

The finer sand contained the following mollusks:

Unio ——, fragments.
Sphærium sulcatum.
Pisidium ——.
Valvata tricarinata.
Planorbis bicarinatus.
Planorbis dilatatus.
Segmentina armigera.
Physa ——, fragment.
Ancylus rivularis.
Succinea retusa.
Succinea avara.

8. *Ordway well.*—This well was excavated on the same terrace-like slope, about an eighth of a mile northeast from the pit.

Measurements of the well section could not be made, but it was plain that the Kansan reaches the surface here, and may be traced upward for 30 feet more (vertically) before it disappears under the loess which covers the ridge in its upper parts. In the well itself bluish Kansan till was clearly discernible. Below this Aftonian sand, with a little gravel, rested on a deep bed of Nebraskan drift. The man who dug the well claimed to have bored into the blue-black "hard-pan" (Nebraskan drift) to a total depth of 175 feet.

An examination of the materials brought up from the well corroborated the correctness of the record. The sand is here clearly interglacial, lying between the Kansan and the Nebraskan drift sheets, and hence Aftonian.

The sand in the well section yielded the following fossils:

Unio ——, fragments.
Sphærium sulcatum.
Pisidium ——.
Valvata tricarinata.
Planorbis bicarinatus.

Some years ago a fragment of a large scapula was obtained from an old gravel pit near this well, and it has been added to the collection (number 91).

9. *Griffin well.*—This is located near Mapleton, Iowa, on the farm of C. H. Griffin, on the east side of section 17, township 85 north, range xlii west. It is situated in a rolling Kansan area about 50 feet above the valley of Heisler Creek.

The section was made through loess, Kansan drift, and into Aftonian sand and gravel to a depth of about 40 feet. The writer examined the material taken from the well. Moreover, Kansan appears at the surface on the same slope at a lower level, the loess covering only the upper parts of the ridge. At a depth of 35 feet a part of the tooth of *Elephas imperator* was found in the gravel.

10. *Wilkenson well.*—This is located in the northwest quarter of section 6, township 85 north, range xlii west. Here, in a typical Kansan drift region, a large tusk (234), a molar, and fragments of cranial bones (numbers 204-211) of *Mammut americanum* were found at a depth of about 35 to 40 feet, in loose sand and gravel. This section is similar to number (9).

11. *Hawthorn pit.*—This is a sand and gravel pit in the same region, being located in the northwest quarter of section 14, township 85 north, range xliii west.

The section is typical, showing loess, Loveland, Kansan drift, and Aftonian, the latter here chiefly sand. Mr. C. A. Hawthorn discovered bones in this at various times, but none were saved.

12. *McCleary pit.*—This is also located in the same region, in the southwest quarter of section 1, township 84 north, range xlii west. The pit is remarkable because it is situated more than two miles inland from the line of the Maple River bluffs, on a small tributary creek. It shows distinct plowing by the Kansan, which here lies distinctly above a stratum of typical Aftonian sand, with some gravel, about 12 feet in depth. The owner reported that in the gravelly portions of the pit he has found "regular clam shells."

13. *County line exposure.*—This is a section made by a road cut along the Little Sioux River, in the north half of section 5, township 81 north, range xliv west, less than half a mile south of the Monona and Harrison County line. The road is here about 25 feet above the Little Sioux River and parallel with it. Three cuts appear in close proximity, making an almost continuous section more than 500 feet in length. The southernmost of these cuts is the best and shows the following:

5. Loess, appearing above the cut and ascending to top of bluff.
4. Loveland, a reddish joint clay, with lines of very large calcareous nodules, more than 15 feet.
3. Kansan, typical bluish, very calcareous till, 12 feet.
2. Aftonian:
   - Fine whitish silt, about 15 feet.
   - Fine silt, mixed with sand, shell-bearing, 5 feet.
   - Coarse gravel, very ferruginous, about 7 feet. This reaches 10 feet in the northernmost cut.
   - Fine cross-bedded sand, 6 to 12 feet.
1. Nebraskan drift, 10 feet exposed, but running out both ways.

More detailed notes on the members of this section follow:

(1.) The Nebraskan is typical blue-black till, breaking up into very small blocks, and containing scattered pebbles and boulders. It is ex-

posed along the road for a distance of about 65 feet, and its upper line is very irregular, but sharply defined. The Aftonian, which lies unconformably on it, has a very ferruginous band at its base.[15]

(2.) The Aftonian is more or less variable in the distribution of its materials. In some parts fine silt appears above, and the sand and gravel are variously disposed. However, they show the characteristic structure already noted and are typical. Large slabs or blocks of sand-conglomerate are found in the sand beds. The measurements of the several parts of this formation as given in the section are maxima. At no point do these appear together, the total being about 20 feet.

(3.) The exposed parts of the Kansan vary in thickness in the several cuts from 0 to 15 feet. None appears in the northern cut, the Loveland resting directly on the Aftonian.

The Kansan is separated from the Aftonian by a sharp ferruginous line.[16]

(4.) The Loveland consists of typical reddish joint clay and varies from 8 to more than 15 feet in thickness.

The fossils were found in the layer of sandy silt, with the exception of the fragments of *Unio*, which were collected in sand in the northern cut. The list follows:

Unio ——, fragments.
Sphærium sulcatum.
Pisidium ——.
Planorbis bicarinatus.
Planorbis dilatatus.
Lymnæa ——, probably *L. caperata*, fragments.

14. *Peyton pit.*[17]—This sand pit is located in the northeast quarter of section 23, township 81 north, range xliv west. The Aftonian here rises about 40 feet above the Soldier River bottoms and is at least 30 feet thick. It is made up largely of sand, but with beds and wedges of gravel, and it presents all the characters of typical Aftonian.

Near the base of the section a bed of white sand 6 to 8 feet thick appears, and just above it, in sand and gravel, a Sioux quartzite boulder measuring 4 by 2 by 1½ feet was found.

Mr. Peyton reports a dark-blue clay under the sand and gravel. This is probably Nebraskan drift.

The Kansan lies unconformably on the Aftonian, which it has evidently plowed in its upper portions, and is very distinct.

The following fossils were collected, the mammals in gravel and the mollusks in sand:

[15] See Bull. Geological Society of America, volume 20, plate 34, figure 1.
[16] See ibid., plate 34, figure 2.
[17] See ibid., plate 16, figure 2.

Mammals:

2. *Mammut americanum*, jaw with 4 teeth (see ibid., plate 25, figure 2).
4. *Elephas* —— (?), part of humerus (see ibid., plate 25, figure 4).
6. *Elephas imperator* (?), femur, 4 feet, broken (see ibid., plate 25, figure 6).
7. *Elephas imperator*, sixth molar (see ibid., plate 24).
9. *Elephas* —— (?), scapula, fragment.
157. Limb bone of proboscidian.
18 (*a*). Rib, unidentified.
56. Camel, first phalanx (see ibid., plate 21, figure 1, and plate 22, figure 2).
66. *Equus* ——, acetabulum.
84. *Equus* ——, part of metapodial.

Mollusks:

Sphærium sulcatum.

15. *Wallace pit.*—This is a sand and gravel pit in the bluffs of the Little Sioux (which are also the east bluffs of the Missouri Valley) near the north line of section 31, township 81 north, range xlv west. Here the Aftonian rises to 35 feet above the valley. The lower part of the section was obscured by a talus, but coarse sand, with some gravel, rises distinctly to a height of 20 feet above the valley. Then follows a stratum of mixed and alternating yellow silt and sand for 15 feet. Above this the Kansan is about 10 feet thick, the Loveland 6 to 8 feet, and on the hill above the section the loess rises to the summit.

The Aftonian is typical. Mr. Wallace opened a pit in the same bluff at a point about 60 yards south, and exposed 16 to 18 feet of gravel. The present pit shows sand chiefly. In this fragments of a *Unio*, or related mussel, were found.

16. *Robinson pit.*—It is located in the southwest quarter of section 16, township 80 north, range xliv west, and is a typical Aftonian section, with Kansan drift and Loveland and loess above. The Aftonian rises to a height of about 40 feet above the valley, and is sharply separated from the Kansan by an oxidized band and by large nodular calcareous plates. It contains very little silt, but is made up chiefly of sand and gravel of the characteristic type.

The following mollusks were collected in the sand:

Unio ——, fragments of thick-shelled species.
Sphærium sulcatum.
Pisidium ——.
Valvata tricarinata.
Bythinella obtusa.
Planorbis parvus.
Lymnæa reflexa.
Segmentina armigera.
Polygyra ——, fragments of a large species.
Vitrea hammonis.
Succinea ovalis.

17. *Cox pit.*[18]—This is located in the southeast bluffs of the Boyer River, in the northeast quarter of section 24, township 78 north, range xliv west, and is one of the finest sections of the entire series. The Aftonian here rises to a height of about 35 feet above the Boyer bottoms.

The section shows the following:

4. Loess, capping the ridge above, but not appearing in the pit.
3. Loveland, exposed just above the pit.
2. Kansan, typical bluish calcareous till, 13 feet.
1. Aftonian:
   - Sand, varying in coarseness, beautifully cross-bedded, 21 feet.
   - Gravel, light colored, cross-bedded, with small boulders, 6 to 8 feet.
   - Gravel, dark colored with much MnO_2, 6 to 8 feet.
   - Fine bluish silt, 6 inches.
   - White sand, penetrated to a depth of 4 feet.

The Aftonian is typical in structure and composition, and both gravel beds contained mammalian and molluscan fossils. No fossils were observed in the sand.

The line between the Aftonian and Kansan is very sharply defined, more or less ferruginous, and with large nodular calcareous plates. Aftonian sand and gravel "boulders," which are scattered through the lower part of the Kansan, also give evidence of plowing by the latter.

The following mammalian fossils were collected:

1. *Elephas imperator*, lower jaw (see ibid., plate 25, figure 1).
16. *Elephas columbi*, molar.
12. *Mammut americanum*, sixth molar (see ibid., figure to left of figure 6, plate 25).
   Mammut americanum, other molars.
42 (*a*). *Mammut americanum*, piece of tusk (see ibid., figure just below left end of figure 4, plate 25).
5. *Elephas* or *Mammut*, right tibia (see ibid., plate 25, figure 5).
18, 25. *Elephas* or *Mammut*, caudal vertebræ.
30. *Elephas* or *Mammut*, pubic bone, part.
138. *Elephas* or *Mammut*, distal end of radius.
45, 46. *Elephas* or *Mammut*, scapula, fragments (see ibid., plate 25, figure 9).
19. Vertebra, unidentified.
57. Incisor, unidentified.
64. *Bos* ——, horn cores (see ibid., plate 23, figure 1).
83. Astragalus of large ruminant (see ibid., plate 22, figure 1).
   Piece of cannon bone of large ruminant (see ibid., plate 22, figure 3).
183. *Camelus* (?), second right inferior molar.

[18] See ibid., plate 2, plate 16, figure 1, and plate 33, figures 1 and 2.

185. *Camelus* (?), second phalanx.
67. *Equus* ——, os calcaneum, 3 specimens.
69. *Equus* ——, proximal end of radius.
72. *Equus* ——, ulna, part.
75. *Equus* ——, scapula, part.
77. *Equus* ——, 3 incisors.
78. *Equus* ——, dorsal vertebra.
79. *Equus* ——, astragalus.
80. *Equus* ——, 4 cannon bones.
81. *Equus* ——, humerus, 2 specimens.
82. *Equus* ——, entire tibia and fragments.
85. *Equus* ——, distal end of femur.
86. *Equus* ——, first phalanx, 3 bones.
87. *Equus* ——, part of large vertebra.
88. *Equus* ——, distal end of radius, 2 pieces.
137. *Equus* ——, distal end of left tibia.
224. *Equus* ——, metacarpal.
70, 120, 123, 126-127, 129-135. *Equus* ——, molars.
116-119, 125, 185. *Equus scotti*, molars (see ibid., plate 18, figures 1-6).
121, 124, 128. *Equus complicatus*, molars (see ibid., plate 19, figures 1-5, and plate 21, figures 2-4).
162. *Mylodon* ——, claw (see ibid., plate 26).
Numerous fragments of bones and teeth.

There were also obtained the following mollusks:

Unio ——, smooth heavy shell.
Unio metanever, 1 valve.
Unio ——, smooth shell.

18. *Peckenpaugh sections.*—These are located on the east side of the Boyer River near the mill-dam, at Logan, Iowa. There are really three sections, but they lie in close proximity and present the same essential facts.

The largest section was made in quarrying rock just above the dam.[19] The quarry section shows the following formations:

Loess and soil, 20 feet.
Loveland, reddish, somewhat sandy, 6 feet.
Aftonian:
Sand, cross-bedded, 7 feet.
Coarse ferruginous gravel, 2 feet.
Missourian limestone, exposed 4 feet.

The water in the Boyer River above the dam is about 5 feet lower than the bottom of this section.

[19] See photograph of this section, ibid., plate 35, figure 2.

A well located just opposite the dam and about 5 rods from the river revealed the following:

Loess, Loveland, } **23 feet.**
Aftonian:
Colored sand, 4 feet.
White sand, 5 feet.
Coarse gravel, 2 feet.
Missourian limestone, penetrated 4 feet.

The top of the well rises 39 feet above the dam.

The third section is in a sand pit, excavated at the level of the road, which is about 23 feet lower than the top of the well.

The following section was shown:

Aftonian:
Sand and finer gravel, 9 to 12 feet.
Fine silt, about 1 foot.
Coarse ferruginous gravel, 18 inches.
Missourian limestone.

It will be noticed that the Kansan and Nebraskan drifts are wanting in all these sections, but the arrangement of the formations present is consistent with the typical section.

The lowest gravel bed is the only fossiliferous part of the Aftonian in these sections. It yielded the following:

Elephas columbi, a good molar, collected north of the middle of the quarry section.
Fragment of a large scapula (?), with the preceding.
Equus (?), a fragment, probably from limb bone of a horse, was taken from the well.
Part of a rib and a fragment of an unidentified bone were taken from the gravel in the sand pit.

19. *Denison pit.*—This is a railway sand pit located near the northwest corner of section 14, township 83 north, range xxxix west, near Denison, Iowa. It is excavated in a detached knoll in the valley of the Boyer River.

The evidence that the sands and gravels in this pit are Aftonian is perhaps less satisfactory than in any of the other sections discussed in this paper; yet the preponderance of evidence favors their reference to that period.

The pit presents the following section:

Loess, light, yellow or slightly brown stained, 2½ feet.
Fine sand, laminated as in dune formation, 5 to 6 feet.

Loess, heavier, yellow with bluish mottlings and ferruginous lines and cloudings, such as appear commonly in older loess, fossiliferous, 5 to 6 feet.

Aftonian sand and fine gravel, 35 feet.

No drift appears in the section, but the lower loess has the appearance of some of the yellower post-Kansan or oldest post-Iowan loess. It is evidently older than the Wisconsin, which might have also left gravel trains in the valley of the Boyer, as that stream drains Wisconsin border territory.

The dune sand layer may correspond to similar formations which are common along the border of the Iowan drift and which were evidently formed in immediately post-Iowan time. The structure of these sands and gravels, their position under an old loess, and their fossils seem to warrant their reference to the Aftonian.

The following fossils were obtained from this part of the pit:

21. *Elephas primigenius*, molar (see ibid., plate 23, figure 2).
28, 29. *Elephas* —— (?), tusks, 2 pieces.
Cervalces ——, part of antler.
Sphærium, probably *S. sulcatum*, fragments.

20. *Offerman pit.*—This sand and gravel pit is located in the Missouri River bluffs in South Omaha, Nebraska. Here the Aftonian beds are typical, and in the western part of the pit the underlying Nebraskan drift is distinct. The workmen have penetrated into the latter about 16 feet.

Above the Aftonian there are about 8 feet of Loveland and 8 to 12 feet of loess.

In the southeastern part of the pit, which is the only fossiliferous part, 8 to 15 feet of Aftonian sand and gravel are exposed, and above these is a very prominent layer of Loveland 30 feet thick.

At other points in these bluffs Kansan till is very distinct between the Loveland and the Aftonian.

The following fossils were obtained from the Aftonian:

Elephas imperator, part of molar.
Equus ——, fragment of molar.

21. *Gladwin section.*—This is located in the east half of section 35, township 71 north, range xliii west, and its position has been described by Calvin.[18]

Here, in a bed of Aftonian silt, a complete set of upper and lower left

[18] Bull. Geological Society of America, volume 20, p. 344.

molars and premolars of *Equus scotti* was found by Mr. Gladwin. (For figure see ibid., plate 17.)

22. *Mad Creek section.*—In this connection it may be of interest to note the discovery of a fossiliferous bed of Aftonian in the eastern part of the State of Iowa. This exposure is located on the east side of North Mad Creek, in the northern part of Muscatine, Iowa, and was examined by the writer in company with Professor Witter. Here a bed of typical Aftonian sand and gravel (chiefly the former), about 25 feet in thickness, rests unconformably on a bed of Nebraskan drift and is separated from it by a strongly oxidized ferruginous band.

The greater part of the Aftonian consists of cross-bedded sand, but near the top it contains a layer of gravel about 1 foot in thickness, from which the late Professor F. M. Witter obtained a fragment of a molar of *Elephas primigenius.*

Overlying the Aftonian is an irregular, slightly pebbly, reddish layer which is probably Loveland. It may, however, belong with the next superimposed stratum, a reddish joint clay which closely resembles a late or post-Illinoisan joint clay which is not uncommon in this vicinity. In either case there is no doubt that the sands and gravels are Aftonian.

Unidentifiable fragments of shells of mollusks were also found in the sand.

It will be seen that in the great majority of these fossiliferous sections the silt, sand, and gravel beds are clearly below the Kansan, while in several they are shown to be above the Nebraskan. Even in those cases in which some of the members of the typical section are wanting, the sand and gravel beds occupy a consistent position with reference to the members which are present. Moreover, it should be borne in mind that throughout the territory herein considered many more non-fossiliferous exposures of similar beds occur, and that these, too, are uniformly consistent with the fossiliferous beds in both structure and position. Again and again the writer has seen non-fossiliferous beds of sand, gravel, and silt lying unconformably between distinct Kansan and Nebraskan drift, thus multiplying the evidence of stratigraphic position furnished by the fossiliferous beds and leaving no doubt as to their horizon.

Are the Fossils Aftonian?

Some question may also arise as to whether the fossils really belong to the Aftonian or were derived from other formations. Fossils from older formations are sometimes found in the Aftonian, as they are in the drifts, and a similar origin might be suggested for the fossils herein discussed.

However, the excellent preservation of the fossils, especially the delicate mollusks, their distribution and abundance, the occurrence of parts of the same skeleton (as in the Akron and Wilkenson sections) in such position that some of the ligaments must have been present when deposition took place, and the fact that the same fossils have not found their way into the drifts, and moreover are not known from any clearly older horizon, all give strong testimony that the fossils are really of Aftonian age.

Conclusions

The following conclusions are based on the field studies here recorded:

1. The silts, sands, and gravels under discussion are interglacial and Aftonian.

2. The Aftonian is widely distributed in Iowa and adjacent territory and is especially prominent in western Iowa and eastern Nebraska.

3. The fauna of the Aftonian, both mammalian and molluscan, terrestrial and aquatic, indicates a comparatively mild climate during that period.

4. The presence of both the large land mammals and the terrestrial mollusks shows that large land areas were exposed in the vicinity of the flooded streams, which evidently transported and deposited the Aftonian sands and gravels.

5. While the Aftonian mammalian fauna has become extinct, the molluscan fauna, so far as it has been observed, has remained unchanged to the present day.

BEDS

deli-
parts
such
eposi-
their
older
onian

rded:
l and

ritory

erres-
that

estrial
of the
onian

e mol-
ged to